A NEW SYSTEM OF GEOLOGY,

IN WHICH

THE GREAT REVOLUTIONS

OF THE

EARTH AND ANIMATED NATURE,

ARE RECONCILED AT ONCE

TO MODERN SCIENCE AND SACRED HISTORY.

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CONTENTS.

BOOK II.

THE ANTEDILUVIAN PERIOD, OR SECONDARY FORMATIONS.

BOOK III.

THE DELUGE,

In which the causes of the antecedent revolutions of the earth, and organic beings are considered.

PREFACE.

The author does not profess, in the following pages, to furnish the geological proficient, with descriptions of new forms of mountain rock, or mineral superposition; nor, had he possessed any such store of original observation, would he have deemed this the fitting occasion to display it. His leading object has been to distribute the most interesting and best established truths, illustrative of the structure and revolutions of the earth, in the order of their physical connexions and causes; whence certain general inductions might be legitimately seen to flow. In executing this task he has drawn freely from every authentic source of geological knowledge within his reach—careful merely to quote his authorities, and to acknowledge his obligations; without descending to such minuteness of reference as might savour of pedantry. He has honestly endeavoured to seek the proper end of philosophy, by arranging multifarious and seemingly discordant facts, into a chain of natural links; an object which, if even partially gained, will constitute the chief novelty, and recommendation of his work.

There is one treatise, the Geology of England and Wales, by Conybeare and Phillips, to which his debt is so considerable, as to call for preliminary avowal. He has followed in his account of secondary superpositions, the route so ably traced in their "inestimable work,"* under a conviction that this island offers in its geology an epitome

* So styled by Dr. Buckland, Geol. Trans. 2d Ser. Vol. II. p. 124. Such also was the sentiment of Dr. Wollaston, that bright star, whose early setting under our horizon, Friendship and Science equally deplore. In one of the familiar interviews with him which rendered my visits to the metropolis so delightful, he pointed to the newly published volume of Conybeare and Phillips lying on his table, saying, "there is a small book for the price, but it is the cheapest that I know."

of the globe, so that the observer who makes himself familiar with our strata, and the fossil remains which they include, has not only prepared himself for similar inquiries in other quarters, but is already, as it were, acquainted by anticipation with what he must expect to find there.* And he indulges the hope that his volume may prove an introduction and incentive to the study of theirs.

The author has likewise diligently availed himself of the ample means accumulated in the *Ossemens Fossiles* of Baron Cuvier, the Philosophical and Geological Transactions, &c. of enlivening the dark catacombs of the earth, by interspersing among his descriptions of its mineral planes, an account of their ancient tenants. By transferring to his pages, systematic exemplars of the analytical science displayed by the great naturalist of France, in restoring antediluvian zoology, he expects to make them peculiarly attractive to the English reader.

In a book intended for general perusal, perhaps an apology may be due for the apparent abstruseness of the chapter on Light. But this was a subject of such vital interest to the proposed line of inquiry, that the author would have deemed himself highly culpable, either to have omitted it altogether, or to have treated it in a more superficial manner. He has spared no pains to simplify the disquisition; and he believes that a moderate mental effort will surmount every obstacle to its comprehension. At any rate, the conclusions are perfectly clear and satisfactory.

The liberal spirit of the Publishers has enabled him to enrich the work with a series of illustrations in copper and wood, numerous and costly much beyond the general rule of the trade; advantages for which he is truly grateful.

Glasgow, Jan. 26th, 1829.

* See Dr. Fitton's eloquent Inaugural Address from the President's Chair, to the Geological Society, Feb. 5th, 1828.

INTRODUCTION.

The formation and revolutions of the earth, are subjects of the highest interest to man, and have exercised inquisitive minds in every age. The first philosophy of Greece consisted of physical cosmogony, discussed, however, in a metaphysical manner. Ideal elementary powers and substances were assumed, to which a multitude of phenomena, ill-observed and falsely grouped, were referred. To deduce one efficient cause from the careful collation of analogous effects, was too humble and irksome a process, for the masters of the Ionic, Italian, or Attic schools. Their spirit was essentially dogmatic. Each arrogated supremacy and infallibility to his creed, using every artifice to kindle the zeal of proselytism in the breasts of his disciples. They, unconscious of the falsehood of their master's axioms, and the sophistry of his arguments, propagated the most absurd tenets without reserve.

Visionaries of this stamp usurped the rank of philosophers, bringing the very name into contempt. Such were almost all the wranglers who infested Athens, and other celebrated cities of Ancient Greece, under the title of Sophists and Sages. After perverting, with impious speculations, the heads and hearts of their countrymen, they have bequeathed in their imperishable language, a legacy of vain imaginations to every coming age. These dreamers have supplied not only our modern metaphysicians with much of their syllogistic chicane, but they have afforded materials of many geological reveries. How humiliating is it to see the best powers of reason, and the holiest aspirations of the heart, still sacrificed by science falsely so called, to these

heathen phantoms; a century after Newton, and two centuries after Galileo, had laid open the true Temple of Nature, in which man is ordained and qualified to offer a reasonable service!

How well this censure of Grecian learning is merited, we may judge from the account given by Brucker, of the philosophy of Leucippus. "The universe which is infinite, is in part a plenum, and in part a vacuum. The plenum contains innumerable corpuscles or atoms of various figures, which falling into the vacuum, struck against each other; and hence arose a variety of curvilinear motions, which continued till at length atoms of similar forms met together, and bodies were produced. The primary atoms being specifically of equal weight, and not being able, on account of their multitude, to move in circles, the smaller rose to the exterior parts of the vacuum, whilst the larger entangling themselves, formed a spherical shell, which revolved about its centre, and which included within it all kinds of bodies. This central mass was gradually increased by a perpetual accession of particles from the surrounding shell, till at last the earth was formed. In the meantime, the spherical shell was continually supplied with new bodies, which, in its revolution, it gathered up from without. Of the particles thus collected in the spherical shell, some in their combination formed humid masses, which, by their circular motion, gradually became dry, and were at length ignited, and became stars. The sun was formed in the same manner in the exterior surface of the shell; and the moon in its interior surface. In this manner the world was formed." According to Epicurus, those atoms which were lightest, mounted up and formed the air, the heavens, and the stars; whilst the more sluggish subsided, and formed the earth on which the human congeries of atoms move about.

That men, by uttering such conceits, should gain the reputation of superior wisdom, would hardly be credited,

did we not meet with modern speculations in Cosmogony no less extravagant, however they be disguised in the scientific language of the day. Our world-framers easily shake off the shackles of inductive logic, and run a fearless career. They will sneer at the pretended infallibility of papal dogmas, and the immutability of papal decrees on the mysteries of faith, but do not scruple to avow doctrines relative to objects of sense, as preposterous as any ever uttered from the Vatican. This persuasion of certainty in his judgments may be somewhat pardonable in the churchman, who believes himself guided by divine inspiration. The student of nature, however, knowing nothing of her attributes, but what he can decipher by vigilant observation of her multiform phases, or by experimental inquiry, should ever preserve the humble docility of a scholar. Like Galileo and Pascal, his only care should be, to arrange in a well ordered series, the record of facts, and collating them by the kindred rules of logic and geometry, to trace out their general results. Into a mind thus disciplined, the spirit of dogmatism can hardly enter. We may rest assured, therefore, that the eager systematist who would heap Ossa on Pelion, to complete his scheme, is no master architect in science.

Bacon was the first who clearly showed the danger of cherishing false notions, which became eventually so incorporated with the understanding, as to occupy it exclusively, to the admission or right perception of truth. His denunciation of these *idols*, as he justly termed them, is perhaps the most valuable part of the *novum organum.* How dangerous such phantoms may become to man, when associated with the mystery of his being and destiny, the history of all Polytheism attests. When we contemplate idolatry, in the abominable rites of paganism, whether barbarous or civilized, we feel ashamed of our common nature thus debased beneath the level of the brute creation. So shocking indeed is the retrospect to the pride of man, that were the

Sacred Scriptures the sole register of such superstitions, their testimony would be scornfully rejected by our modern Stoics, who, while surrounded by an almost universal empire of passion and appetite, have the effrontery to proclaim the innate goodness, perfectibility, and dignity of human nature. Now, though the worship of the molten statue, the block, the reptile, or the host of heaven, may have ceased among us, idolatry still prevails in more insidious forms. The philosopher fashions, after his own caprice, strange gods, he adorns their images with every meretricious art, and sets them up to the adoration of mankind. Such is the idolatry of a more refined age, which successive Idealists have remodelled from time to time. Each is eager to supersede or dethrone the governor of the universe, and to substitute in his stead mere physical forces, acting in a continuous or interrupted train, to suit their fantastic germs of organic and inorganic being.

Metaphysical systems have had their day of fashion. The world will no longer be agitated with researches which move in a vortex, without visible progression. Under this impression, Pyrrhonists begin to fight with the more solid weapons of physics; though the principle of their warfare, the exclusion of divine agency, be still the same. Lightly esteeming, or disregarding altogether, the concerns of the unseen and future world, and concentring all their thoughts and affections round the present pleasures and vanities of life, they are willing to recognise matter as the only source of their being, and physical forces as the sole creative and conservative powers. Like the giants of mythology, they ransack every region of their mother earth, internal and external, for arms against the Invisible Omnipotence, and thence rise up with delusive vigour to the combat:

——————— —— "Cum tetigere parentem,
Jam defecta vigent renovata robore membra."*

* Lucan, Lib. IV. v. 600.

The structure and revolutions of the earth, as explored by Geology, have opened a vast field, in which the champions of scepticism and revelation have latterly waged incessant warfare. In this contest, however, passion and prejudice have too often usurped the place of knowledge, on both sides, and hence a victory has often been claimed by either party. Yet no truce between the combatants can take place, far less a final discomfiture to the enemies of religion, till it be shown that the physical events appertaining to the creation and the deluge, as described by Moses, are not discordant with the legitimate deductions of physical science. Believing both systems of knowledge, that of Inspiration and Nature, to emanate from the same Author, we may rest assured that each, if rightly understood, will harmonize with the other. Whenever dissonance is produced between them, it may be traced to the touch of an unskilful or an unhallowed hand.

However momentous the interests involved in this inquiry may be, it demands, however, the utmost delicacy and circumspection. Every approach to controversial acrimony should be deprecated. The advocates of religion do not always bear in mind that compassion is the only feeling which they are allowed to entertain towards those who unhappily want the faith essential to salvation. The more violent their rejection of the Christian doctrine, the more gentle should its teachers be in addressing unbelievers. Dogmatic virulence never made a convert.

I am well aware that the Mosaic record of creation has been often expounded, in a manner equally hostile to science and religion. Many commentators on sacred writ have unwittingly afforded handles to argument and ridicule, against which the text itself was entirely proof. This blending of revealed and natural knowledge has been denounced by Professor Playfair, in the following terms, the poignancy of which might be more keenly felt by Theologians, had not the philosopher himself, carried back his

geological inquiries to a period still more remote and mysterious, than they have ever done. "Proceeding in direct opposition to rules that have never yet been violated with impunity, and mistaking the true objects of a *theory of the earth*, they carry back their inquiries to a period prior to the present series of causes and effects, where, having neither experience nor analogy to direct them, they pretend to be guided by a superior light."* In animadverting on the geological schemes of Kirwan and Deluc, with just severity, he says, "With a spirit as injurious to the dignity of religion, as to the freedom of philosophical inquiry, they have disregarded a maxim enforced by the authority of Bacon, and by all our experience of the past. '*Tanto magis hæc vanitas inhibenda venit et coercenda, quia ex divinorum et humanorum male-sana admixtione, non solum educitur philosophia phantastica, sed etiam religio hæretica. Itaque salutare admodum est, si mente sobria, fidei tantum dentur, quæ fidei sunt.*'"

"If vain conceits," says Bacon, "come to be held in veneration, the understanding succumbs as if seized with the plague. Some moderns have indulged in this vanity with so little discretion, that they have endeavoured to establish a body of natural philosophy, on the first chapter of Genesis, the book of Job, and some other of the sacred writings; thus seeking the living among the dead. This vanity merits castigation and restraint the more, as from the mischievous admixture of divine and human things, there is compounded at once a fantastical philosophy, and a heretical religion. It is therefore most salutary, with a sober mind, to render to faith, what belongs to faith."†

The censure here bestowed on those who construct schemes of philosophy on scripture texts, is perfectly just, but it does not apply to those who endeavour to prove, by

* Playfair's Works, Vol. I. p. 467.

† Novum Organum, Aphor. LXV.

inductive evidence, that the conclusions of philosophy are not discordant with the order of physical events, recorded by Moses. The object of Bacon's reprobation is not the besetting sin of the present age. Science must now be built up on its own foundations, by its own rules, and with its own materials. The individual who would attempt to deduce a single principle in science from any phenomenon described in the Bible, would be regarded as no friend either to philosophy or religion. But when the principles of physics are fairly established on their own bases, it becomes a subject of interest, to examine how far certain natural phenomena related by the inspired historian, are conformable to our digest of the laws of nature. If an accordance can be clearly made out between things so distinct and independent, as ancient testimony, and the results of modern research, faith and reason will enjoy a joint triumph, propitious to their mutual influence on mankind.

This procedure is just the inverse of what Bacon reprobates. We do not seek the living among the dead; we do not determine the existing or actual properties of matter, from a few brief notices of mighty revolutions which it anciently suffered. But like Cuvier, confronting the bones of fossil animals, with the bones of their living types, we compare certain phenomena and results of early occurrence, on our globe, with the sequence of phenomena passing before our eyes, drawing from the records of faith, only such facts as belong to faith; viz. such as can be learned from inspiration alone. Surely those who frame a system of Cosmogony which removes entirely out of sight, the Creator and Governor of the world, tend as powerfully as ever Deluc and Kirwan did, to form a fantastical philosophy and a heretical religion.

Theologians are much more open to Bacon's censure, than philosophers. If any one will compare the diversities of meaning which have been assigned to the Hebrew words contained in the first verses of Genesis, by such of our com-

mentators on the Bible, as have theorised on the phenomena of creation, he will be convinced that no solid foundation for geological science, need be sought for in the field of Hebrew criticism. Yet on this basis, all our early, and many of our later Bible scholars, have created schemes of accordance between nature and revelation, producing too often a *male-sana admixtio* of divine and human things. I humbly conceive that the only concern of the biblical student with Cosmogony, is to ascertain that the results of physical research in the earth and the heavens, do not essentially impugn the Mosaic text in its plain interpretation, as addressed to plain men of all ages and nations. They ought, therefore, to inquire first of all, by the rules of inductive logic, what are the scientific results most unequivocally established, and next to examine, whether any of these be irreconcilable with the commonly adopted version of Genesis. In following this course with discretion, no rule of right reasoning need be violated, if we be duly sensible of the difficulties of the subject, the imperfections of science, and the fallibility of human judgment. On the contrary, I hope to convince the candid reader of the following pages, that the Divine Spirit in furnishing two guides to man, revelation and reason, has benevolently given them so many points of affinity, that a diligent search may cause their accordance to become manifest to every docile mind, showing them to be really close and powerful allies, instead of lukewarm friends, or open foes, as their common enemies would allege.

Such is the perversity of human judgment on subjects the most momentous, that one hardly knows at times whether to regard it more in ridicule or sorrow. The classical scholar, for example, will pore over Herodotus and Xenophon with a sort of superstitious reverence, while he is too ready to view Moses with indifference or even contempt. Yet for sublimity and depth of thought, set forth with simplicity and pathos of recital, neither the father of

profane history, nor its most eloquent son, can vie with the legislator of the Jews. In the authentic stamp of consistency, the prime merit of historians, the civil can certainly bear no comparison with the sacred. The former contradict each other broadly on the greatest characters and transactions, such as those of Cyrus, though at no great distance from their own times, while the latter is always in perfect accordance with himself, as well as with ancient monuments and traditions. To Moses we are indebted, moreover, for the only rational account we possess of the origin and filiation of the different tribes of men. As to the alleged absurdity of his code of laws, and the cruelty of his injunctions for exterminating idolatry, if we measure them on the great scale of Providence, we shall admit, that the establishment of a pure and perfect Theism, among a central nation of the earth, was not too dearly purchased by the ritual observances of the Jews, or any punishments inflicted on the cruel and licentious Canaanites. Let us bear in mind that in the ordinary course of nature, 30 millions of individuals, annually fall victims, over the face of the globe, to disease, old age, famine, the sea, or the sword, and that, therefore, the destruction of a thousandth or even a hundredth part of that number for a great moral purpose, affords no peculiar ground for impeaching the wisdom of God, or the veracity of his interpreter. The results eliminated from the physical researches of the present volume, display the primary developments of the material system, and the great revolutions of the earth in such surprising harmony, with the master touches of the Hebrew prophet, as to constitute, in my opinion, incontestable evidence of his being endued with a knowledge more than human; for he has indicated a style and sequence of natural phenomena, gainsayed or disowned by all human learning, till the profound and novel investigations of these latter days, have unveiled their truth.

Holding in due reverence, therefore, the Mosaic record,

and ready to recognise the finger of Providence directing every event of the material world, we are not on that account called upon to renounce or fetter the exercise of our intellectual powers, on any subject, competent to their tribunal. The rhapsodies of fanaticism, and the bigoted subjugation of science, to certain figurative expressions in scripture, are alike to be shunned. Revelation was certainly not imparted to mankind, for the purpose of instructing them in any principles of philosophy, which reason can explore. When the phenomena of nature are described, it is always in popular language, corresponding to the informations of sense. Thus the sacred writers, in common with practical astronomers of every age, speak of the sun and stars as rising, setting, and moving, in the firmament, yet neither our astronomers, nor the scriptures, are thereby supposed to pronounce a judgment on the actual motion or repose of these luminaries. This is a proposition left to science to investigate. The heavenly bodies apparently revolve in determinate orders and periods, with regularly recurring phases. These have been laid open to the observation of man since the origin of his race, offering him every requisite instruction as to the times, distances, and paths of their revolutions, as well as to the magnitudes, densities, and figures of the spheres. Whatsoever lessons these phenomena have given to the present age, were held forth to the past, and will be exhibited to the future. Astronomy never reverts to a state of repose, antecedent to their actual condition. It contemplates the velocities and mutual equilibrium of moving bodies, but does not venture to speculate on a former or a future state, an origin or an end of the actual appearances of the heavens. In this respect, astronomers differ widely from our two famous geologists Werner and Hutton, who do not confine their inquiries to the existing cycle of phenomena, but boldly remount to a hypothetical order very different from the present, which no human eye ever witnessed. They do not scruple to

describe the terrestrial constitution, which preceded and gave birth to the one, which they see, just as if an astronomer were to trace out the nascent forms and movements of the sun and planetary orbs. But neither, possesses the *data*, requisite for the solution of his problem. The astronomer, well aware of this defect, and trained in the severe discipline of geometry, abstains from such vain speculations. But the geologists of the above schools, disdaining to acknowledge incapacity, and restrained by no rigid calculus, advance fearlessly into their pristine chaos, and assuming the creative function, construct their favourite terrestrial schemes out of pre-existing confusion. They find no difficulty in bringing ancient chaos to its end, and in originating an entirely new order of things. To produce an effect without a cause never disturbs their philosophy. Their chaos of eternal, or at least, indefinite duration, changes under their direction, into systematic arrangement and succession. Elemental strife is speedily converted into the most friendly affinities; a confused mixture and turmoil, into crystalline forms, and parallel strata.

Now, such procedure as this, indicates a march of presumption, wholly unlike the modest pace of inductive science. Nor will its arrogance appear less odious when we consider, that in travelling into an ideal chaos out of the actual world, in order to forge a series of transition links between them, these theorists disdain to inquire whether their natural darkness might have had the benefit of a few rays of supernatural light; whether the origin of the earth, a fact beyond the cognizance of man, and yet of great moral interest to him, may not have been kindly communicated to his race, by the same Being, who gives him life, and breath, and all things. Such deference might have been expected, at least, in Werner and Playfair, who acknowledged the divine inspiration of the Bible. But it does not appear that either of these ingenious men, regarded the Mosaic narrative of creation, as giving any

physical instruction whatever concerning the origin of the earth. We shall afterwards find, that the Mosaic chronology throughout, was equally disregarded by our learned countryman. It would have been well for his mathematical reputation, had he, in this instance, bestowed a little of that faith on Moses, which he unluckily lavished on Bailly.

Amid our absolute ignorance concerning the origin of our terrestrial system, it would therefore seem not unreasonable to consider such facts as the Deity has thought fit to reveal concerning the formation and garnishing of this globe as an abode of vegetable and animal beings. These facts may be very few, no more than are merely sufficient to teach the pious mind to confide in the GREAT FIRST CAUSE, instead of losing itself in an endless labyrinth of conjecture. But still they should be held as fixed points, in neglecting which we shall probably deviate into error. It must be remembered, that science has here no fulcrum to rest her leverage upon. Vainly, therefore, would she strive to move the earth out of the place assigned to it by the inspired historian. "Who is this that darkeneth counsel by words without knowledge? Where wast thou when I laid the foundations of the earth? Declare if thou hast understanding? Whereupon are the foundations thereof fastened? Or who laid the corner-stone thereof?" Job, chap. xxxviii. These questions accurately circumscribe the boundaries of Cosmogony. They say to it, "Hitherto shalt thou come and no further; and here shall thy proud thoughts be staid."

None of our physical records are better fitted to inculcate humility, than the geological systems of the 18th century. They exhibit the human mind, in gesture proudly eminent, but yet the perpetual dupe of phantasms, as extravagant and unreal as the prodigies of oriental fiction. They remind one of the reveries which were afloat in zoology at an earlier period. That animals might be produced without parents or *ova*, by the fortuitous fermentation of

stagnant pools, was a favourite dogma with some theorists, under the name of equivocal generation. Thus they concealed their ignorance by giving a technical term, a verbal quibble, instead of an explanation of phenomena; and thus also they set entirely aside Divine agency in the creation and conduct of the world. This monstrous dogma necessarily disappeared, when natural history proved that every animal has a parental germ of life. The Pyrrhonists, dispossessed of the animal kingdom, have latterly seized on the mineral, and boldly adventured to account for its origin and arrangement by their old scheme of equivocal generation. The execution of this scheme has not, however, been so easy as its abettors had fondly hoped. These world-makers split into several sects, whose chief delight was to demolish the work of their rivals. By this philosophic warfare, the older and more ricketty combatants have been driven from the field, leaving it in possession of two reckless champions, Werner and Hutton, the worshippers of Water and Fire. Both agree in only one respect; the original crudeness and imperfection of that terraqueous mass, which they have undertaken to refine and complete. Diverging from this point, each proceeds to show how the present appearances of the earth have been produced by the action of the ordinary forces of nature. By successive developments and catastrophes, which they profess to detail, the clumsy offspring of Deity or Chance, for the parentage is not well defined by them, becomes, in a countless lapse of ages, fitted to discharge its functions in the material system.

Our age and nation never cease to extol Bacon's inductive logic, and the rigid demonstrations of Newton. One is naturally led to suppose, that those who so loudly profess to be their disciples, should imitate, in some degree at least, the methods of research prescribed and practised by these great masters of reason and science. We should expect to find the facts subservient to any doctrine, collected with labour and skill, examined with scrupulous caution,

and lucidly arranged without deceptive art. It is only facts, thus carefully chosen and candidly compared, which can be generalized into a just theory. If we examine the ablest expositions of the Wernerian and Huttonian geologies by that philosophic standard, we shall find them to fall egregiously short. Phenomena doubtful, or discordant, are indiscriminately pressed into the service of these hostile sects; while the whole structure of their arguments is frequently baseless, resting on no solid facts, nay, hardly countenanced by a plausible analogy. Yet they claim for their hypothetical conclusions, the confidence due to sober induction alone.

The true epoch of philosophical geology can scarcely be traced farther back than Mr. Smith's Mineralogical Map of England, and the foundation of the Geological Society of London. Since then, the Cosmological schools have been waning fast away. But as the above rival systems, engrossed so very lately a large share of attention, and still have many partisans in the world, they merit a slight review, merely considered as sports of the human intellect.

The theory of Hutton was passing fast into oblivion, like its visionary predecessors,* when it was re-embodied for a season, by the eloquence of Playfair. Delighted with the imposing boldness of the Huttonian creed, the Professor undertook its exposition with the ardour of a mineralogical neophyte. Bringing to the task, the joint resources of dialectics and geometry, he produced those *Illustrations of the Huttonian Theory* which have been so highly celebrated by his literary friends, though they will probably add nothing to his fame as a philosopher.

Were a modern naturalist to teach that the various classes, orders, genera, and species of animals and vegetables, were, on their first emergence, crude and shapeless

* The cosmologies of Leibnitz, Whiston, Demaillet, Buffon, Dolomieu, Bertrand, &c.

monsters; but that the several parts progressively acquired their just size and form in the course of successive generations, by the contending actions of the vital and chemical forces, mankind would not hesitate to pronounce the author of such speculations insane. Does the terraqueous globe, on which countless orders of living beings depend for accommodation and subsistence, so nicely suited to their peculiar organs and instincts, does it display no evidence of pre-concerted and pre-adapted wisdom in its structure? Originally a crude and rugged mass, did it gradually acquire its actual form and constitution from the antagonist powers of waste and reconsolidation tending towards their present equilibrium, during indefinite ages? This question, which Professor Playfair answers in the affirmative, contains his favourite proposition, whereby he pretends to give physico-mathematical proof to his adopted theory.

"Now, it is not at all obvious to what physical cause this phenomenon" (the spheroidal figure of the earth) "is to be ascribed. The earth, as it exists at present, has none of the conditions that render the assumption of the figure of equilibrium in any way necessary to it. Constituted as it is, its parts cohere with forces incomparably too great to obey the laws of statical pressure, or to assume any one figure rather than another, on account of the centrifugal tendency, which results from its revolution on its axis. Though the fluidity of the earth will account for the phenomenon of its oblate figure, it may reasonably be questioned, whether this fluidity can be admitted in consistency with other appearances. According to what was established above, none of the appearances in the mineral kingdom indicate more than a partial fluidity in any former condition of the earth. The present strata, made up as they are of the ruins of former strata, though softened by heat, have not been rendered fluid by it, and have even possessed their softness in parts, and in succession, not altogether nor at the same time. . . . . Since neither the hypothesis

of the Neptunists, or the Vulcanists,* affords any good explanation of the figure of the earth, or such a one as can connect it with the other appearances in its natural history, it remains to inquire, whether the system that supposes a partial and successive fluidity, like Dr. Hutton's, has any resource for explaining this great phenomenon.

"On this subject Dr. Hutton has not treated; and when I was first made acquainted with his system, it appeared to me a very serious objection to it, *that it did not profess to give an explanation of so important a fact, as the oblate figure of the earth.* On considering the matter more closely, however, I found that there were principles contained in it, from which a very satisfactory solution (*and I think the only satisfactory solution*) of that difficulty might be deduced. This solution I shall endeavour to explain, in as far, at least, as is necessary for the purpose of general illustration.

"It is laid down in Dr. Hutton's theory, that the surface of the earth is perpetually changed by the detritus of the land; and from the materials thus afforded, new horizontal strata are perpetually formed at the bottom of the sea. If this be true, and if the alternations of decay and renovation have been often repeated, it is certain, that the figure of the earth, whatever it may have originally been, must be brought at length to coincide with the spheroid of equilibrium.

"Suppose now, a body like the earth, but with its *actual figure infinitely more irregular*, having a sea circumfused around it. . . . If we suppose the solid parts of this mass subject to be dissolved, or worn away, and carried down to the ocean, there will be a tendency to give to the whole body the same figure that it would have assumed, if it had been entirely fluid, and subject to the laws of hydrostatics. . . . Also, whatever be the irregularity of density, the tendency to a change of figure will not cease,

* The followers of Werner or Buffon.

till the body is moulded into that particular spheroid which admits of being covered with water, every where to the same depth. Thus it appears, that a solid of an irregular figure, and of irregular density, provided it be in part covered with water, and be at the same time subject to waste, above the surface of the sea, and reconsolidation under it, has a tendency to acquire, in time, the same figure that it would have acquired, had it been entirely fluid.

"In the preceding reasonings, we have supposed the process of decay, and subsequent stratification, to be carried on without interruption, till the whole of the land is covered by the sea. This supposition is useful for explaining the nature of the forces which have determined the figure of the earth; but there is no reason to think that it has ever been realised in its full extent, the elevation of strata from the bottom of the sea, interrupting the progress, and producing new land in one place, as the old decays in another. The very same land, also, which is wasted at its surface, may perhaps be lifted up by the forces that are placed under it, or it may be let down, undergoing alterations of its level, from causes that we do not perceive, but of which the action is undoubted. But notwithstanding these interruptions, the general tendency to produce on the earth a spheroidal figure may remain, and more may be done by every revolution, to bring about the attainment of that figure, than to cause a deviation from it. This figure, therefore, though never likely to be perfectly acquired, will be the *limiting* or *asymptotic* figure, if it may be so called, to which the earth will continually approach. . . .

"That no very irregular figure is found among the planetary bodies, may therefore be considered as a proof of the universality of that system of waste and reconsolidation, that we have been endeavouring to trace in the natural history of the earth. . . . .

"Thus, Dr. Hutton's theory of the earth comes at last to connect itself with the researches of physical astronomy.

The conclusion to be drawn from this coincidence, is to the credit of both sciences. When two travellers, who set out from points so distant as the mineralogist and the astronomer, and who follow routes so different, meet at the end of their journey, and agree in their report of the countries through which they have passed; it affords no slight presumption, that they have kept the right way, and that they relate what they have actually seen.

"It must be allowed to the Neptunists, that the fluidity of the whole earth is not necessary to account for its assuming the spheroidal figure. It is sufficient, if the whole of that crust, or shell of matter, was fluid which is contained between the actual surface of the terrestrial spheroid, and the surface of the sphere inscribed within it; that is, of the sphere which has for its diameter the polar axis of the earth." This amounts to about $\frac{1}{150}$ of the whole bulk of the earth; and as the mineral substance of the crust will take, at the lowest estimate, 600 times its volume of water to dissolve it, no less than four times the bulk of the whole earth is required by the Wernerian systematists to effect their primordial solution of the superficial rocky crust. "Such, therefore, at the very least, is the quantity of water which Mr. Kirwan supposes, after it ceased to act in its chemical capacity, to have retired into caverns in the interior of the earth. Thus the Neptunists in their account of the spheroidal figure of the earth, are reduced to a cruel dilemma, and are forced to choose between a physical and a mathematical impossibility."*

Had the Professor regarded the hypothesis of his friend, Dr. Hutton, with equal impartiality as that of Werner, he would not have expended any refined analysis in its support. That the planets had at one time "an actual figure *infinitely* more irregular" than the present, is certainly a very strange proposition for a modern philosopher to

* Playfair's Illustrations, Note xxv.

make, one equally extravagant with any Epicurean fiction in Lucretius. After an indefinite period, it appears that one of them at least, the earth, became sufficiently regular for an abode of living beings. Their habitation has, however, a precarious existence. The progress of waste will eventually crumble down its mountains, and strew their *detritus* over the bottom of the sea, converting our imperfect spheroid into the perfect form of equilibrium. This geometrical symmetry which conspiring physical forces tend, by this creed, to produce, should some day cover the whole land with a windingsheet of water, universally fatal to organic motion and life. This mortal consummation, however, they propose to obstruct from time to time, by fortuitous explosions from the central fires, upheaving mountains and plains, as they are wanted, to rescue the world from a watery grave. The probability of such a mode of salvation is rapidly diminishing; for it is admitted by the theoretic votaries, both of Vulcan and Neptune, that these igneous eruptions are becoming vastly feebler and less frequent, than they were in ancient times; that volcanic fires are fast expiring, and only a few smoking spiracles remain to attest their former activity. In this predicament, the Huttonians can hold forth to proselytes but slender hopes of the duration of their system. The casual convulsion of a dying power, is a very precarious resource, and can be little relied on for resisting the steady pace of destruction. The earth of the Huttonians must become a finished spheroid, unfit for every useful purpose.

Mr. Playfair's two travellers, the celestial and terrestrial, would have found a better coincidence, and one more to their credit, as philosophers, by tracing at once the actual and only beneficial form of the earth, and its fellow planets, to that perfect wisdom which created all things in conformity to their destined ends, and which provides with unwearied beneficence, for the wants and well-being of every organic tribe.

I have no desire to fatigue my readers with a detailed examination of the theory propounded by Hutton, and embellished by Playfair. Its defects and inconsistencies, and indeed its whole hypothetical tenor are now so notorious, that no practical naturalist of eminence will venture to adopt its conclusions. My sole object, here, was to unveil its vain spirit of theoretic cosmogony; to exhibit its efforts to build a Babel-tower that should make a name, and enfranchise it from the control of a creating and directing Providence. The world, according to Hutton, shows no trace of a beginning, or of an end; but has been the theatre of an indefinite series of transformations in time past, and will continue to be so in time to come. The mountains of a former earth were worn down and diffused over the bottom of a former ocean. There they were exposed to the agglutinating power of subjacent internal fires; and after due induration, were heaved up by the explosive violence of the same force, into the inclined or nearly vertical positions, in which the great mountain strata now stand.

The mountains of gneiss and mica slate, allowed by every practical geologist to be primitive, are barren in animal exuviæ. Now these most distinctly stratified rocks, were formed, it is said, at the bottom of the Huttonian sea, by the same process as the calcareous and other secondary strata that are replete with shells. Whence do these organic ruins come, and why are they absent in the former class of rocks, both of them formed in the same sea, and under similar circumstances? They cannot reply that the epoch of the gneiss and mica-slate formations was anterior to the existence of animals; for their theory affirms, that the present earth sprung up out of a preceding one, by a spontaneous growth or transition, without the intervention of a divine creative energy. They tell us, that in an indefinite series of ages, the mountain masses of the pre-existing globe became submarine concentric layers of rock, which were

thence elevated by catastrophe into the present dry lands. Their marine deposition was slow and tranquil, disturbing the general economy of nature no more than at present, and consequently, not interfering with the production of marine testaceous animals, nor with the distribution of their shelly exuviæ. Hence, should these beds be eventually indurated and heaved up by the subjacent fires into the nearly vertical mountain schists of a new earth, they must contain the organic witnesses of their submarine formation. But since our actual mountains of gneiss and mica-slate are destitute of these internal witnesses, as also of their basis, carbonate of lime, they cannot have been ormed at the bottom of an ocean teeming with animal life. Devoid of organic remains, they indicate a sea devoid of vital energy. The first appearance of shelly strata is coincident with a specific exertion of creative power.

This mortal chasm, in the succession of mineral formations, breaks the chain of the Huttonians. It is the death blow of their theory; demonstrating that the present earth has resulted from definite creative *Fiats;* and not from the progressive operations of any merely physical forces whatsoever. It is therefore to be regretted, that a mind so accomplished as that of Professor Playfair, should have devoted so many studious years to the decoration of the phantom described by him in the following paragraph.

"How often these vicissitudes of decay and renovation have been repeated, is not for us to determine; they constitute a series, of which, as the author of this theory has remarked, we neither see the beginning nor the end; a circumstance that accords well with what is known concerning other parts of the economy of the world. In the continuation of the different species of animals and vegetables that inhabit the earth, we discern neither a beginning nor an end; and in the planetary motions, where geometry has carried the eye so far both into the future and the past, we discover no mark either of the commencement or of the

termination of the present order. It is unreasonable indeed, to suppose, that such marks should any where exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in his works any symptom of infancy or old age, or any sign by which we may estimate either their future or past duration. These phenomena then are all so many marks of the lapse of time, among which the principles of geology enable us to distinguish a certain order, so that we know some of them to be more, and others to be less distant, but without being able to ascertain with any exactness, the proportion of the immense intervals which separate them. These intervals admit of no comparison with the astronomical measures of time; they cannot be expressed by the revolutions of the sun or the moon; *nor is there any synchronism between the most recent epochas of the mineral kingdom, and the most ancient of our ordinary chronology*."*

Our ordinary chronology comprehends the deluge, a great epocha of the mineral kingdom, the truth of which is obviously discarded by Mr. Playfair. In the third part of the present work, ample evidence will be adduced from Cuvier and other practical naturalists, of the reality of that recent epocha, and of its synchronism with our chronology. Moreover, it will be shown in our second part, that the mineral strata contain formations which "discover marks of the commencement" of the different species of vegetables and animals that peopled the earth. The Astronomical comparison is a strange solecism for so acute a logician to commit. The cases are quite discrete, and destitute of any true analogy. The laws of the planetary motions are represented in a system of mechanical theorems, which relate solely to *co-existing* phenomena. The principles of their actual equilibrium apply equally to all past and future

* Playfair's Illustrations, § 118 and § 124.

time. The appearances reveal nothing in the past, or the future, different from the present, except change of relative position among separate masses. The physical constitution of the planets, which could alone afford, in their interior metamorphoses, kindred or parallel facts for geology, are beyond our cognisance. In the mineral structure of the earth, we shall find symptoms of infancy, as well as on its surface, considered as the dwelling place of man.

A very brief survey of the principles of the Neptunian theory of the earth, will evince *it* also to be an idol set up by a vain philosophy, to usurp the rank and functions of a creative intelligence.

" Anciently," says Werner, " a vast solution covered all the globe, rising above the highest mountains. This great *chaotic ocean*, very different from our existing seas, contained the elements of the primitive lands. The most ancient of its products, namely, the rocks on which all the others repose, are also those which constitute the most elevated summits; those which form the greater part of the most prominent points of the globe, with the exception of the volcanic mountains. Over and around their tops, we find the mineral masses which were deposited immediately thereafter. They envelope the former in the shape of beds of great extent, and they are enveloped in their turn by other beds. In proportion as these deposits are newer, their extremity or upper edge, appears at a lower level.

" Thus, above a certain height, we find nothing but granites; a little lower we have gneiss; lower still, we see the successive appearance of mica-slate, clay-slate, and the other primitive formations. Those of posterior formation proceed with a continually declining level. The most ancient of these still stand at considerable heights; but the more modern, such as chalk, and the later formations of gypsum, occupy only the lower districts of the terrestrial surface. Finally, the great alluvial territories exist merely in the low plains, or at little elevations above

the level of the sea. These facts lead us to conclude that the solution, in whose bosom the different mineral masses were elaborated, has successively lowered its level; and that from an elevation above our highest mountains, a gradual diminution has reduced it to the level of our present seas." In the later geognostic works published in Germany, on the principles of Werner, the several mineral formations are regarded as having been produced by four great irruptions and subsidences of four successive seas.

" The above solution successively changed its nature. Its first mineral precipitates were very different from the following ones; and these also differed from their successors. At the beginning, they were chiefly granites; in the middle period of the mineral formations, schistose or slaty strata abounded; and in the last stage, calcareous rocks began to predominate. The change in the nature of the precipitate was sometimes abrupt, but more commonly it took place in gradual succession. Thus, among the first mineral formations, the principles of felspar were most abundant; these diminished by degrees, while those of mica increased; and in consequence of this alteration, gneiss, mica-slate, and clay-slate appeared. The limestone, which was rare in the early stage, occurred subsequently in more abundance, forming the principal ingredient of the later deposits. Magnesia became remarkable, chiefly towards the middle of the first period; some time after that, coal began to show itself, and progressively increased in the middle era.

" While the solution covered and enveloped the whole surface of the globe, it formed a clear and tranquil liquid of great depth. At this time, its products were entirely crystalline. Thus, when we contemplate a piece of granite, and examine the distinct grains or small crystals of quartz, felspar, &c. which compose it, the segregation and arrangement of their integrant particles denote a mineral formation made with leisure and tranquillity.

" In proportion as the level of the liquid sank down,

the agitation appears to have augmented. The crystallisation became confused; the particles had no longer an opportunity of coming forth separately, as in the first epocha, so as to form considerable crystals. Hence arose those fine-grained granites which form the paste of porphyries; those mica-slates in which the grains of quartz, and the spangles of mica are amorphous, and are difficult to distinguish. Finally, chemical separation ceased to take place, or be practicable; the crystalline aspect disappeared, and nothing but homogeneous masses were produced, whose texture became more and more loose and earthy, till their translucency vanished. The serpentines, the slates, and even the limestones furnish examples of these gradations. At last, the turbidity having increased to a still greater degree, and the precipitation becoming more rapid, the mineral deposits became mere earthy masses, feebly indurated; they were now simple sediments.

"Werner supposed that frequent oscillations had modified these successive formations. Before the large grained crystalline granite had passed into schists of a clayey or sedimentary quality, nature often retraced her steps for a season. After making mica-slates, and even clay-slates, she thought fit to reproduce some granites; and it was not till after several such alternations, that she advanced in a decided manner, to form the great schistose mountains.*

I believe this outline of Werner's theoretic notions to be genuine. The authority is apparently most legitimate, that of his favourite pupil, M. D'Aubuisson, engineer in chief of the royal corps of mines in France, "who was honoured during four successive years with the confidence of his master, Werner, and favoured with a disclosure of geological principles which he himself never submitted to the press."

It would be superfluous, indeed, to offer an elaborate refutation of a world-building hypothesis, so extravagant,

* D'Aubuisson Traité de Géognosie, Tom. I. pp. 355, et seq.

so visionary, and so inconsistent with every principle of mechanical and chemical science. Whence arose that immense chaotic ocean, within whose bosom the summits of the Himmalaya and the Andes were crystallized? Whither did it retire in measured stages of descent, to allow the primary and secondary rock formations, to lay their successive platforms, in the amphitheatre of the globe? The atmosphere has a finite extent, not expanding into space beyond a limited distance from the earth; and thus that world of waters could not escape into another sphere, in vaporous exhalations. The quantity of water requisite to cover the globe to the height of the Himmalaya, or 27,000 feet, would be as great as the whole mass of our actual ocean. Werner was too little of a philosopher to calculate that his crystallization plan called on him to provide a receptacle for 1000 millions of cubic miles of water. The great density of the interior body of the earth, precludes the possibility of that receptacle being subterranean. Since neither celestial nor terrestrial space will admit his retiring chaotic ocean, itself must be deemed an inadmissible supposition. Even granting its reality, and allowing moreover that this water was adequate to dissolve the now insoluble granitic mountains, so as to form a clear and tranquil fluid, we may ask, why the solvent that then exercised so marvellous an affinity for the siliceous and aluminous earths, came so soon to discard them altogether from its bosom? The attractive force that made the solution, should have maintained it. To imagine an effect to come to pass without a cause, is sufficiently ridiculous, though not without a parallel in modern philosophy; but to expect a solidifying action, a stony deposit, from a liquefying agent, unabated in force and magnitude, is truly absurd. The other assumption of the clear and tranquil solution becoming spontaneously muddy and disturbed, as it parted with its solid contents, is repugnant no less to common sense, than to chemical experience. A still liquid containing soluble and

insoluble matter, usually deposits the insoluble, which is mechanically diffused, before the crystals appear, provided the latter be regularly aggregated, as occurs in granite. We shall not waste more words on this analysis; but conclude with expressing astonishment that the theoretic dreams of Werner should ever have been regarded as realities, in the present age. The old Cosmogony of Leucippus is not more irrational at bottom, and would appear equally plausible, if decked out in fashionable technology.

Buffon's wild fancy of the planets having been originally ignited masses, thrown or struck off in fusion from the sun, and afterwards left revolving round him at distances, and with velocities proportional to the detaching forces, seems to have suggested the geological hypothesis of Cordier. These theorists agree in supposing that an indefinite period of refrigeration had elapsed before the crust had become cool enough to suffer the vapours to condense into water, and to maintain vegetable and animal beings. Fourier has exercised his profound mathematical skill in proving, that the state of calorific equilibrium is now nearly attained, or that the waste by radiation into celestial space is nearly compensated by the expansion of heat from the central parts of the earth, and the absorption of heat from the sunbeams at its surface. This proposition is possibly just, though it will require a century at least of exact thermometric observations, to place it among the inductive truths of science. This for the future; but for the past, we have not the slightest evidence that our terraqueous globe first existed as a molten mass ejected from the solar furnace. Such an assumption is undeserving of place or respect in natural philosophy.

From a long series of observations, made with powerful telescopes, Herschel concluded that the solar light and heat do not emanate from the body or nucleus of the sun, but from certain phosphoric and pyrophoric clouds, which are produced and developed in its atmosphere. He thought

that this immense light-exciting ocean is violently agitated over its whole surface, causing those corrugations of its disc which he has so well described, and which indeed may be observed through a telescope of moderate powers, by an even unpractised eye. When this superficial stratum is broken through, and widely separated, we may discern either the black veil of subjacent solar clouds, or even the solid dark nucleus of the sun itself. Hence Herschel accounts for the dark spots which frequently bestrew the sun's disc, and for the shelving margins which surround them. Across these excavations of the phosphoric film, bridges of luminous matter are seen to stretch, which extending in breadth, finally cause the dark chasm to disappear, and restore to the sun all its original brightness. The area of one of these black spots is often much greater than the whole surface of the terrestrial globe. When the eruptive storm subsides in the solar atmosphere, the equilibrium of its parts replaces the luciferous layer. Is is well known that these spots, first observed by Galileo, led to the discovery of the sun's motion round its axis, and showed that this motion is accomplished in twenty-five days and a half. Had Buffon been acquainted with these great excavations of luminous matter, he would probably have ascribed them to a projection of the solar substance giving origin to some new planet or comet, and causing diminution of the sun's heat proportional to the darkened portion of its orb. But Herschel has shown, on the contrary, that the seasons in which the solar spots are most abundant, are characterised not by decreased emanation of light and heat to the earth, but apparently by an opposite result. We hence infer, that these spots correspond, and are owing to an increased activity in the vibratory motions, by which the sun excites the luminiferous ether, diffused through space.

The new improvements in optics afford a very unexpected means of determining whether it be true, as Herschel imagined, that the solar light does not issue from an incande-

scent solid or fluid. In fact, when such a body raised to a very high temperature, becomes luminous, the rays which fly off in all directions, do not come from the outer surface only, but also proceed, as the rays of heat do, from a multitude of material points placed beneath or within the surface, to a certain depth, extremely small indeed, but actually existing. Now, such of these rays as traverse the envelope of the heated mass obliquely, acquire and preserve a peculiar property, which can be rendered sensible by experiment; they are polarised. But if the same mass, instead of being rendered luminous by its proper temperature, be only covered with an exterior film of flame, which is the source of its light, the rays do not then possess this property.

Science has thus been enabled to submit to this singular test, the light which the sun sends to us. M. Arago, the author of this beautiful experiment, and by whose labours physics and astronomy have been often enriched, has in fact discovered, that the rays of the sun, when transmitted even obliquely, are not polarised. It is therefore obvious, that in regard to the point in question, the opinion proposed by Herschel is immediately deducible from the latest discovered properties of solar light.

These results are fatal to Buffon and the various Vulcanists of his school. Such theorists can no longer have recourse to the sun as a furnace out of which to scoop ignited spheres; for the nucleus of that luminary may possibly enjoy a habitable planetary temperature.

Two motives have engaged me to undertake the present work. First, a desire to lay before the world a view of certain intrinsic sources of change in the constitution of the earth, which seem to have escaped the observation of philosophers, but which appear to me deducible from modern physical and geological discovery. Second, a wish to lead popular students of philosophy, to the moral and religious uses of their knowledge.

Science has lately gained a vast accession of votaries. During the first twenty years of this century, the only public endowment in Europe for teaching the scientific principles of the Arts to Artisans, by regular courses of lectures, was that founded by Professor Anderson, first administered for three years by Dr. Birkbeck, and ever since by myself. M. Dupin's favourable report of the beneficial results of my tuition among the Glasgow Artisans, published in his Tour through Great Britain, in 1817, drew general attention to the diffusion of science among the people; and within a few years of this date, the Edinburgh School of Arts, the popular lectures in the Conservatory of Arts in Paris, and the Mechanics' Institutions of London and other cities were established. Such is the spirit now diffused among the multitude, that from the capital to the hamlet, Newton and Laplace, Lavoisier and Davy, have become household words. The plodding mechanic fancies himself suddenly grown an adept in Dynamics, and the apprentice boy a master of Statical problems. We are not to wonder, that when physics first unfolds its Diorama to their view, it should raise their minds to a state of morbid excitement, and give birth to strange imaginations. We may even expect to encounter much of that dangerous dogmatism, which a little learning is apt to inspire. But these transition disturbances will subside, as sound knowledge is gained.

Were nothing but substantial inductive science presented in these seminaries, neither the mental nor moral constitution of the multitude would be exposed to any hazard. During the first 17 years of my popular courses, till about the year 1820, most of the Proprietors of our great Factories encouraged the attendance of their Journeymen and Apprentices on the Lectures, and frequently distributed tickets of admission to the most deserving, under a conviction that both their dispositions and talents were thereby improved. About this period, a general schism between the Masters and Workmen began to spread through the manu-

facturing districts of the kingdom. At the same era, it was, that the schools for popularising science began to be established. This coincidence in time, has afforded unluckily, a colour for ascribing to philosophy the spirit of misrule and irreligion, which then took possession of many minds, previously docile and pious. Nor will any one deny, that if under the pretence of expounding to students the elements of mechanical or astronomical science, the teacher shall insidiously undermine the principles of natural and revealed religion, and promote the desire, too common, alas! of emancipating the conscience from the control of an Omniscient Witness, and an Unerring Judge; he may render the school of philosophy a pesthouse of morals. Even those pseudo-philanthropists, who, reviling the doctrines of faith, and renouncing the powers of a world to come, pretend, by human sanctions and expedients, to erect a kingdom of virtue and happiness in this world, should beware of placing such scorners in the chair of philosophy, lest by loosening the frame work of society, they bring down a second fearful crash of atheism and crime:—

> "Grave ne rediret seculum Pyrrhæ
> Nova monstra questum."—HOR.

But certainly, the science of the Newtonian school, taught in the spirit of its illustrious author, is propitious to man in every rank of life, promoting his piety as a Christian, his kindness as a master, and his fidelity as a servant.

That all knowledge is in every case and in every degree a good, and ignorance the parent of every evil, are popular maxims of the day; and seem, at first sight, to be equally sound in theory, and safe in practice. But they cannot be received without much modification. With knowledge, responsibility increases, and failing fulfilment, guilt; "For by the law is the knowledge of sin. Nay," says a great master of morals, "I had not known sin but by the law." Knowledge is therefore an essential element of

criminal purpose and criminal action. It may communicate power indeed; but if power be so imparted to a malignant being, that knowledge will become the parent of evil. This consequence has been enforced with great felicity of illustration in the story of Caliph Vathek, a philosophical romance, which clearly shows how increase of knowledge in a wicked mind, may merely aggravate misery and vice. This is also the great moral of Gœthe's Faust, and the Manfred of Byron; two of the most powerful personifications of the workings of unhallowed knowledge, ever imbodied by genius.

> "They who know the most,
> Must mourn the deepest o'er the fatal truth,
> The tree of knowledge is not that of life."—Byron.

Even in our daily experience, we learn to our cost, that the most knowing of our acquaintances, are not always either the safest or the best.

Knowledge, in its ordinary acceptation, is power; and it is nothing more. It is a weapon which may effect good or evil, according to the intention with which it is wielded. It gives force and permanence to despotism, whether of the many, or the few. There is no doubt another and a better sense in which knowledge may be taken, but one too seldom implied in philosophical disquisition,—the knowledge of the Being and Will of God, as conveyed in the Scriptures. This knowledge likewise confers power, but not the power of doing evil. The consciousness of a superintending Omnipotence must restrain criminal desire, and promote virtuous principle.

It is therefore devoutly to be wished, that the strenuous, and in general laudable efforts, now making to diffuse knowledge and its concomitant power among the people, should be made conducive to the welfare of mankind at large. When the streams formerly pent up in narrow channels on elevated land, and there accessible to only a few

vigorous minds, are drawn off in numerous rills to irrigate the lower levels of society; the prudent Philanthropist, in spreading the refreshing waters over the thirsty soil, will be careful in its distribution. He will not inundate his fields at random, lest he sap the vigorous roots, and loosen the tender ones altogether. The system may, in fact, be judged by its fruits; for if its leading partisans be men of turbulent or dissolute lives, it may be deemed pernicious.

The objects, order and changes of the material system may be contemplated through the medium of either an insane* or a sound philosophy, according as they are considered to be the offspring merely of certain developing forces miscalled Nature, or as the creation and ordinances of the one living and true God. The first plan of study sedulously conceals or even seeks to efface the many features of wisdom and goodness impressed on his works; the second diligently deciphers them as the best and highest lessons of philosophy. Thus the *Système du Monde* of Laplace, leaves the mind afloat in a dark and viewless void; while *Newton's Principia* lead our thoughts up to the Father of Light and Life.

"The *greatest benefit* which the sublime science of astronomy can confer, is, to dissipate the fears occasioned by extraordinary celestial phenomena, and to destroy the errors resulting from ignorance of our true relations with nature, errors the more deplorable, as social order must repose solely on these relations. Truth and Justice are its immutable laws." Such is the grand peroration of Laplace's masterly exposition of the system of the world, presented to his countrymen in the fourth year of the Republic. What a very different work would his eloquence have penned, if unchilled by the scepticism of that period, his bosom had been kindled by a spark of the diviner fire which sanc-

* "Insanientis dum sapientiæ,
Consultus erro."—Horat. Carm. I. 31.

tified the soul of Newton! Let us now hear *his* conclusion of the whole matter. *Elegantissima hæcce solis, planetarum, et cometarum, compages, non nisi consilio et dominio entis intelligentis et potentis oriri potuit. Hic omnia regit, non ut anima mundi, sed ut universorum dominus. . . . . Et hæc de Deo, de quo utique ex phenomenis disserere, ad philosophiam naturalem pertinet.* "This most elegant system of sun, planets, and comets, could not have existed but by the will and command of an intelligent and powerful Being. He regulates all things, not as the soul of the world, but as the Lord of the universe. Him we see, only in his powers and attributes; him, we admire, in his most wise and excellent structure of things, in his final causes, and perfections; him we venerate and adore, in his government. We worship him as servants; for a God without dominion, providence, and final causes, is nothing else than fate and nature. From a blind metaphysical necessity, always and every where the same, no variation of things could proceed. The whole diversity of the Universe, in its several places and times, could only have arisen from the ideas and will of a self-existing Being. And these are the conclusions concerning God, which flow from the phenomena of Nature, by the principles of Natural Philosophy."

"The first end to which all wisdom or knowledge ought to be employed, is to illustrate the wisdom or goodness of the Father of Nature. Every science that is cultivated by men, leads naturally to religious thought, from the study of the plant that grows beneath our feet, to that of the host of heaven above us, who perform their stated revolutions in majestic silence amid the expanse of infinity. With reverential awe, every great or elevated mind will approach to the study of Nature, and with feelings of adoration and gratitude, he will receive the illumination that gradually opens upon his soul. It is not the lifeless mass of matter, he will then feel, that he is examining;—it is the mighty machine of Eternal Wisdom: the workman-

ship of Him, ' in whom every thing lives, and moves, and has its being.' Under an aspect of this kind, it is impossible to pursue knowledge without mingling with it the most elevated sentiments of devotion;—it is impossible to perceive the laws of nature, without perceiving at the same time, the Presence and the Providence of the Lawgiver,—and thus it is, that in every age, the evidences of religion have advanced with the progress of true philosophy; and that science, in erecting a monument to herself, has, at the same time, erected an altar to the Deity."—*Alison.*

Negligent of these truths, it has become the fashion with several systematists to obliterate from their transcript of Nature, those traces of creative design which have been inscribed on every page of the original, for the delight and elevation of the student's mind. This is a deed of singular demerit, derogatory at once from the well-being of man, and the glory of God. Should the harmonious co-operation of the elemental powers, light, heat, and electricity, towards their manifold subjects, solid, liquid, and aeriform, be contemplated as the preconcerted wisdom of Heaven, this idea is scouted as fanatical. Are Final causes, or the purposes of individual being, no longer to be sought after *soberly* in physics, because, forsooth, in the infancy of science, phantasms were taken for realities in this delicate research? The same rule should make us renounce every scientific inference; because, in one shape or another, it may have been absurdly drawn before. Final causes, the conditions of existence, or the correlation of parts and functions, constitute the unceasing study of the genuine Naturalist, who investigates the principles of organic life. Because Galen, in his treatise *de Usu Partium*, has given unfounded fancies for final causes, is Cuvier to be denounced for inferring the shape and size of an unknown animal, its tribe, genus, and species, whether living or extinct, from a single fossil bone? In fact, final causes, or the mutual uses and subserviency of parts, are his sole guides in this intricate labyrinth.

We readily admit that the time has not arrived, and may perhaps be still far distant, when the experimental philosopher may safely employ final causes as the *leading* clue in his inquiries. In the history of ancient, and the early periods of modern physics, final causes were often assigned, before the proximate or operative causes had been explained, or perhaps examined. This inversion of inductive logic, need hardly be apprehended from any experimentalist of reputation in the present day. In such circumstances, therefore, the temperate use of final causes may be encouraged, first as serving to arrange several inductions under a general head, but especially as displaying the concerted harmonies of Providence. The outcry against them is one of the countersigns of the sceptical school.

Physical lessons for youth and the people should be selected with care. That the system of nature has been, and may be exhibited, in so distorted a form, as to impress improper images on the common mind, will hardly be denied by the most zealous partisan of the *knowing faculties*. On this delicate topic, I gladly avail myself of the following acute remarks from a work, distinguished for the liberality of its views.

"In sober truth, doubts are excited in minds, that had never heard of doubts, or suspected their existence. Tremaine gives the means of doubting, but he does not give the antidote. His counter arguments will not confer the power of reasoning, the feelings side invariably with the devil, and the result is consequently obvious. It is not by the dry statement of opposing arguments, that the dialogist can carry the victory which he feels he possesses in himself; the affections or the prejudices, human depravity or human pride, takes a part; the bias is on the wrong side, and he who does not like to be convinced, naturally sides with the antagonist."*

* Westminster Review, Vol. IV. p. 301.

This is a sufficiently humiliating account of the natural propensities of the human heart. Discretion should therefore be exercised in preparing mental food for the people. Only sound articles should be served up, and such equivocal speculations be witheld, as may readily ferment into moral poison. In the course of my own public experience during a quarter of a century, I have often observed the avidity with which every phenomenon apparently adverse to natural or revealed religion is seized, and the reluctance with which it is renounced by the will, long after the fallacy has been made manifest to the understanding.

Thus, for example, I have met with individuals of considerable pretensions to candour and sagacity, who having devoured with greedy eyes, the story told by Brydone, in his Sicilian Tour, about the Canon Ricupero, conceive that it justifies them in reviling the chronology and character of Moses. The Canon, though a weak enough theorist, was a man of undoubted piety, and had certainly no desire to call any Bible truth in question. Dolomieu, who knew him, censures severely the Scottish traveller for his ungenerous return to the Canon's hospitality, in unhandsomely exposing him to ridicule, and but for his excellent private character, to the castigation of the church. Ricupero is said to have fancied that a bed of lava required 2000 years to gain a coating of soil, by the decomposition of its surface. Having observed in a pit in the neighbourhood of Ætna, 7 lava beds lying over one another, with a stratum of rich earth between each, he was said to infer that the mountain was 14,000 years old. His bishop is also reported to have counselled him not to make his mountain older than Moses had made the earth; a most philosophical advice, as we shall presently see.

The facts exhibited by Ætna are so directly hostile to any such conclusions, that we can hardly suppose the Canon ever to have formed them; and are led to suppose the story a mere jest, got up in contempt of the Canon's feelings, to

please the dissolute society, in which Brydone is known to have lived for some time. Let us see what a geologist says, in treating of Ætna, who probably never heard of the Scotchman or his travels.

"The lava of 1157 is covered with 12 inches of vegetable earth proceeding from its own decomposition; that of 1329 is covered with 8 inches. On the other hand, several of the lavas of Auvergne have maintained an entire surface, all over blistered, and bristling with asperities, whose edges and angles are still sharp and well preserved. We might even imagine these lava streams to have just flowed from the bowels of the earth, and that they had hardly had time to cool. It is, however, probable that these lavas have lain on the soil of Auvergne for 3000 years, exposed to the action of the elements. Two thousand years have elapsed since Cæsar encamped upon them; and even in his day tradition could tell him nothing about their origin. The fertility of the lands on Ætna, however, is a subject of admiration to all who visit the mountain."*

Here we see, in the first place, that no inference whatever can be made as to the age of a lava, from the state of its surface. The tendency to decompose differs in every specimen. We see, in the second place, that in 500 years a good vegetable mould may be formed, which multiplied by 7, carries us back to a period only 600 years after the deluge.

Prior to the appearance of Brydone's book, Sir William Hamilton had shown that over Herculaneum in less than 1700 years, "the matter of 6 eruptions has taken its course over that which lies immediately above the town, and was the cause of its destruction. These strata are either of lava or burnt matter *with veins of good soil betwixt them.*† Here 243 years are enough for decomposition, instead of Brydone's 2000.

* D'Aubuisson Geognosie, Tom. II. pp. 592, 593.

† Philosophical Transactions, Vol. LXI. p. 7.

But the most singular evidence remains, about this castle of scepticism. In Dr. Daubeny's interesting sketch of the geology of Sicily, drawn up after an extensive tour lately made in the island, we have the following description of the beds of lava in the famous pit, at Aci Reale, on which Ricupero was made to speculate.

"At all events Brydone has been grossly deceived in imagining, that the seven beds of lava seen lying, one above another, near the spot, have been sufficiently decomposed into vegetable mould; the substance which really intervenes between the beds being nothing more than a sort of ferruginous tuff, just similar to what would be produced by a shower of volcanic ashes, such as usually precedes or follows an eruption of lava, mixed up with mud or consolidated by rain. Of course, his inference with respect to the antiquity of the globe, falls to the ground, as being founded on the fact of the decomposition of so many beds of lava, which turns out to be altogether a mistake."*

Geologists have begun, of late years, to survey the structure of the earth in more minute and patient detail, than their dashing predecessors; to compare, by map and section, its most interesting provinces; to contemplate individual facts directly, and not through the dark and distorting medium of a master's cosmogony; and to examine, with zoological skill, the organic inscriptions of its different strata. In thus studying to decipher the volume of its shelly records, they have explored many mysteries, inscrutable by Werner, Hutton, and the early fanatics of their schools, to whom the very alphabet of the language was unknown. In this new field of knowledge, the English nation stands pre-eminent; against no mean rivalry, however, of the naturalists of France. Emulation has here produced the happiest effects; for while the mineral super-

* Edinburgh Philosophical Journal, Vol. XIII. p. 266.

positions of England have received admirable illustration, from the sagacity of Smith, Greenough, Macculloch, Conybeare, Phillips,. Buckland, De la Beche, Webster, Winch, and several other members of the London Society, Brogniart and Von Buch have revealed many wonders in French, Swiss, and Italian geology, and the two Cuviers, Blainville, Lamarcke, and Defranee, have thrown surprising light on the zoology of fossils. By directing his profound knowledge of comparative anatomy, to antediluvian osteology, Sir Everard Home has gathered fresh laurels; nor have the German and Italian mineralogists been forgetful of their fame in this difficult career. The joint labours of all these philosophers, have been embodied by a master's hand, along with his own unrivalled studies in the *Ossemens Fossiles* of Baron Cuvier; a magnificent production of which, it is difficult to say, whether the science, eloquence, or candour, be most worthy of admiration.

By such conspiring researches, an interesting gradation has been traced in the species of organic exuviæ distributed throughout the secondary strata, in their order of superposition. *Each successive mineral bed is the sepulchre of a peculiar colony of shellfish.* These relics of life have thus acquired singular importance. They furnish stereotype pages, so to speak, by which the corresponding or equivalent geological formations may be read and recognised in every terrestrial zone, however interrupted the mineral planes may be, by ravines, mountains, or seas.

Shell-limestone constitutes the main body of secondary formations; which indeed may be regarded all together as only one enormous calcareous stratum, forming, with a few interruptions, the external envelope of the solid mass of the globe, and alternating occasionally with ranges of gypsum, marl, sandstone, and clay.*

* That conchiferous strata are as common in remote regions, as at home, the general reader may learn from the following account of the structure of rocks in places, with whose names, at least, he must be familiar.

The lowest of these beds are characterised by remains of the simplest forms of animals, to which, in the living state, the name polyparies is given; formerly zoophytes from a mistaken notion of their participating also in the nature of plants. To this family belong Madreporites, Encrinites, Corals, Alcyonites, &c.* In the next strata, molluscous exuviæ occur; animals still of a very simple structure; of which the earliest specimens are Orthoceratites, Ammonites, &c. These have now no analogues among living beings. Rising among the secondary planes, we find in our coal strata, plants of species unknown to these climates, enormous reeds, bamboos, ferns, &c. The calcareous strata which succeed the coal, contain shells in great profusion, though still of kinds different from those found in our actual seas. They are termed numismalites, belemnites, gryphites, terebratulites, &c. Bones of fishes, and *oviparous amphibia*, such as crocodiles, turtles, and some reptiles, begin to appear a little further up, but sparingly scattered among the shells, with which the rocks now teem, and frequently to such a degree, as to compose nearly the whole of their substance. Among the superior calcar-

" Palestine appears to be composed principally of secondary limestone, intermingled with trap-rocks. Thus the country between Jerusalem and Jaffa is compact limestone: the hill on which Nazareth is built is of a gray-coloured compact limestone; the field of blood, mentioned by St. Matthew, is of friable limestone; David's cave (1 Samuel, xxiv.) appears also to be situated in limestone; the mount of Olives is of limestone, in part granular; limestone occurs in the valley of Jehoshaphat; the rocks around the pool of Siloah are of limestone; on Mount Zion the rocks are of a conchoidal grayish siliceous limestone; Mount Lebanon appears principally composed of limestone; Mount Carmel is interesting, on account of the large balls of quartz contained in the limestone; all the rocks in fine around Jerusalem are of compact limestone, in which also the numerous tombs in the neighbourhood are hewn. Mount Tabor, Bethel, Capernaum, seem to be also calcareous."—*Silliman's American Journal, June*, 1825.

* See a great variety of these beautifully figured in the second volume of Parkinson's Organic Remains.

eous and marly strata, the testaceous remains, resemble more nearly the genera of living animals. We here observe also bones of *lamantines*, whales, and other cetaceous fishes, along with a few vestiges of birds. In the superior and more recent beds, bones of land animals occur; but different from our existing genera; such are the Palœotheria, Anoplotheria, Pterodactyles, &c. Last of all, in the superficial layers of loam and gravel, which cover almost every land, animals near akin to living beings, though still specifically distinguishable in some respects, lie buried. Here the bones of the fossil elephant, rhinoceros, hippopotamus, &c. have been exhumed.*

We can now perceive what precision, geology may derive from the circumstance, that at two remote points in the plane or order of the same mineral formation, we may expect to meet the same general family of marine shells. "Thus," says Mr. Conybeare in his excellent introduction to the Geology of England and Wales, "If we examine a collection of fossils from the chalk of Flamborough Head, Dover Cliff, Paris, or Poland, 8 species out of every 9 will be the same. We shall observe the same echinites associated with the same shells; nearly one-half of which echinites will be found to belong to divisions of that animal tribe, unknown in a recent state, and indeed never met with except in beds of chalk. If we next proceed to inspect parcels of fossils from the carboniferous limestone, from whichever locality it may be brought, we shall find them the same in kind; the same corals, the same encrinites, the same product terebratulæ, spiriferæ, &c. But between the organic remains of the chalk and mountain (carboniferous) lime, not one of the same animal species will be found, hardly any thing possessing resemblance."

These facts seem to indicate that as each peculiar soil, exposure, and elevation, on the surface of the earth, bears

* D'Aubuisson and Cuvier.

its peculiar families of plants, so each peculiar mineral bed deposited on the floor of that primeval ocean, has bred its peculiar tribes of animals. The texture of our shell limestones or marbles, would lead us moreover to conclude, that in these ancient seas, a *nidus* of calcareous paste has been plentifully diffused, in which were tenderly imbedded, the most delicate shells elaborated from it in countless myriads.

That conchiferous strata, occupy a large portion of the surface of the earth, has been generally known for ages; even Ovid tells us that we inhabit sea-born lands, *(factas ex æquore terras.)* Accurate accounts and figures of corals and shells were published in the year 1714, by the learned Buttner, who removed every rational doubt respecting the origin of these bodies, and rendered it manifest that all these fossils had primarily been inhabitants of the ocean. Even prior to that period, Bernard Palissy, a Parisian, had proved that the fossil shells of our strata, were animal remains that had been deposited in the sea; and that the impressions of fishes, occasionally found on stones, were actual casts of these marine animals.

Yet Voltaire, supposing these shells to countenance the Mosaic narrative of the deluge, (though, in fact, they do not belong to that event, but to prior epochs of the world,) issued the following infidel rescript, from the Vatican of Ferney. It is a good specimen of the philosophy of the sect, and may help us to judge into what panics the truths of revelation are ever ready to throw the herd, when the leader is obliged to weave such a veil of sophistry and falsehood, in order to hide a mere phantom from their view.

"There are some errors," says Voltaire, "which are only for the people, there are others only for philosophers. Perhaps one of the latter kind is the notion entertained by many naturalists, that they perceive, all over the earth, evidences of a general *bouleversement* (subversion). There has been found in the mountains of Hessia, a stone which seemed to bear the impression of a turbot, and on the Alps

a petrified pike; and it has thence been concluded, that the sea and the rivers have flowed time about over the mountains. It was more natural to suppose that these fishes were carried thither by a traveller, who, on their getting spoiled, threw them away; and they became petrified in process of time. But this idea was too simple and too little systematic.

"There have been also seen in some provinces of Italy, France, &c. small shells, which are asserted to be natives of the sea of Syria. I do not mean to contest their origin, but ought we not to call to mind that innumerable crowd of pilgrims, and crusaders, who carried silver to the Holy Land, and brought back shells? And would people rather believe that the sea of Joppa and Sidon, came to cover Burgundy and the Milanese? No system can give the least probability to the idea, so generally diffused, of the ocean having rested a long time over the now habitable earth, and of men having formerly lived where porpoises and whales at present roam. *Nothing in vegetable or animal life has changed; all the species have continued invariably the same.*

"Some persons discovered, or thought they discovered, a few years ago, the bones of a rein deer, and of a hippopotamus, near Etampes, and thence concluded that the Nile and Lapland had been anciently on a pilgrimage to Paris. But they should rather have supposed that some virtuoso had possessed formerly in his cabinet, skeletons of the rein deer and hippopotamus. A hundred similar examples invite us to examine a long time, before we believe."*

* I have translated the first paragraph from his Dissertation in 1749, on the changes which have happened to our globe, and the second from his singularities of Nature, published in 1768.

Voltaire's lust of fame, and pride of literature, led him to make a public display, without compunction or reserve, of every spectre of philosophy that haunted his restless brain. In 1738, he published *Elements of the Newtonian Philosophy*, without understanding, or being able to solve, a single problem of the Principia. He competed in the same year for a prize from the Academy of Sciences, by an elaborate dissertation

On so absurd a text, any comment is superfluous.

The monuments of changes in the constitution of animal and vegetable beings, and of an universal deluge which was fatal to them both, are so marvellous and multiform, that Baron Cuvier, by their means, has had the talent to create as lively an interest for the ancient empire of the dead, as for the kingdoms of living nature. In accompanying him through the dark cemeteries of the earth, a mysterious gleam from the primeval world penetrates our soul, and solemnly awakens its deepest faculties. We seem to walk among new orders of beings, endowed with extraordinary forms, and exercising paradoxical functions. In one sepulchre we meet with a sloth, not dwarfish as a small dog, like our existing species, but of the gigantic stature of a rhinoceros, provided with enormous arms and claws for suspending itself, according to the instincts of its kind, from trees of colossal growth. In others, we find quadrupeds bearing wings on their toes, crocodiles furnished with fins, but no feet, and lizards of whale-like dimensions. These all speak of a world unlike our own, the fashion of which has long passed away. But that world, the victim of sin, will not have perished in vain, if its mighty ruins serve to rouse its living observers from their slumberous

on Fire, though all unversed in experimental physics. In 1741, he addressed to the same learned body, a Memoir on *Living Forces*, a controverted problem in Dynamics, while he was unskilled in mechanical science. His Dissertation on the *Changes that have happened to our Globe*, appeared in 1749; a work equally remarkable for its ignorance of every branch of Natural History, and presumptuous dogmatism. And finally his *Singularities of Nature* came forth in 1768. Here his hatred to Moses has hurried him into a violation of many scientific truths, which it was shameful for him, at that period of discovery, not to know, or knowing to gainsay. The profligate hypocrisy of the French noblesse and churchmen under the Regent and Louis XV. tended to produce in minds gifted like Voltaire's, reaction against a Christianity so corrupt and heartless. Thus superstition becomes the parent of infidelity, a result equally exemplified in much of modern Europe, as it was in ancient Greece.

existence, if they lead them to meditate seriously on the origin and end of terrestrial things, and to improve their brief span by the contemplation of the works and ways of Providence. Thus, as the stream of civilization advances towards the general diffusion of knowledge, truth, and piety, over the earth, new chambers of nature are unlocked, new scenes of instruction are disclosed, and new means and motives of intellectual and moral excellence are presented to our view.

The above demonstrative documents, however subversive of the reveries of Brydone and Voltaire, will hardly be held decisive, by resolute doubters. Freethinkers have, in fact, little freedom of thought. Slaves to the dark power, which their appetites and passions worship, they dare not admit the light of truth into their bosoms. Philosophy must therefore be allowed to have its bigots as well as Religion; and the former are certainly neither the most amiable nor the least dangerous of the two. Let such as withold their assent from this proposition, consult the Memoirs of Baron Grimm and his associate Annalists. There they will see how far the Idolatry of scepticism tends to cherish purity of life, generosity of heart, gentleness of temper, elevation of sentiment, truth, humility, candour, and all the germs of moral excellence. And let us bear in mind that the individuals so graphically portrayed, were of highly accomplished minds, and polished manners. Yet it is among them particularly, that we may discern the infant form of that philosophic Hydra, which soon thereafter reared its hundred heads in France, sickening the nations with its breath. The atmosphere, though purified by the supervening storms, which desolated Europe, still contains some of the effluvia, ready to enter every predisposed breast. But their agency is no longer restricted, as at first, to the upper sphere of speculative *savans*. Their grosser particles have settled down among the lower grades of society; they are disseminated in the trade-wind of periodicals; and

have converted many a workshop and cottage, erewhile scenes of honest industry and quiet, into arenas of deceit, misrule, and intemperance.

Beings thus perverted with the pride of corrupt doctrines, lose all relish for pure knowledge. They turn a deaf ear to the strains of divine philosophy, however wisely she may charm. These are a few of the miserable trophies of anti-theism; these the fruits of a little learning, divorced from its divine origin and end.

To stem this foul torrent by forcibly raising mounds in its way, would be a useless labour. We must remount to its sources, and give them a wiser and a safer direction. We must lead the lofty streams of science into the legitimate channels, wherein they will flow without disastrous inundation, and spread happiness and fertility on every side. Thus they may once more become the waters of life, refreshing its labours here, and guiding it onwards to the regions of a blessed eternity.

Placed for a quarter of a century, at the head of the Parent Seminary for diffusing Science among the people, and an eyewitness of many of the evils above described, it will not, I presume, be deemed unbecoming my character and functions, if I shall humbly endeavour to draw forth the accordances of Science and Revelation, in the Structure and Revolutions of our globe. May I indulge the hope of strengthening by this means, the faith of the pious, and of removing many chimeral obstructions, in the path of truth, so as to enable the candid student to discard his turbulent doubts, and "find joy and peace in believing."

A NEW SYSTEM OF GEOLOGY.

BOOK I.—THE PRIMORDIAL WORLD.

CHAP. I.—GENERAL OBSERVATIONS ON THE FORMS OF MATTER.

The Objects to be examined in this Book are the General Forms of Matter, Light, the Atmosphere, and the Primitive Structure of the Terraqueous Globe.

UNIFORM experience proves that every species of matter, however different its essence may be, is susceptible of assuming three most distinguishable forms; the solid, the liquid, and the gaseous or aerial; of which forms we have familiar examples in ice, water, and vapour or steam. We learn, by scientific research, that each particular form depends on the relation between two opposite and contending powers; the attractive and repulsive. When the former power predominates, solidity prevails; when the latter, gaseity or the aerial state; and when the two are nearly balanced, the liquid condition results. Intermediate or transitive forms are also possible, such as the semi-fluid, and the semi-gaseous, but to these two no importance is attached, in our present inquiry.

The attractive force is that, which under various modifications, gives origin to cohesion, tenacity, hardness, crystallization, and gravitation. Had *it* reigned alone in the terrestrial system, every thing would have been condensed into a motionless mass, in which water and air would have been as fixed as the solid rock.

This, therefore, is the natural condition into which the attractive particles of matter spontaneously tend to come, and at which they do arrive, unless counteracted by the divellent force, called caloric or heat.

Chemical experimentalists have been too easily led away in their notions of this power, by certain vague analogies with their own familiar elements; and have spoken of it as a peculiar elastic fluid, pervading the pores of all bodies, in different quantities, according to their specific heats, and their actual temperatures. They talk of its transfer from one body to another, upon any change of capacity, or any disturbance of the thermometric equilibrium; of its radiating from surfaces by a continuous efflux, and thus projecting its particles to the greatest distances with inconceivable velocity. But insuperable difficulties attend the very conception of such a radiating and self-acting fluid. Associated with light in the sunbeam, heat must also follow its theoretic fortunes. If light consist in certain vibratory affections of an elastic ethereous medium, so must heat. Experiments demonstrate that the calorific power extends beyond the limit of the red rays, in the prismatic spectrum, or is less refran-

gible than them. It must, therefore, consist of longer oscillations than those which we shall see constitute red light, and which are one forty thousandth of an inch in length. Such undulations at a certain intensity will expand the ponderable matter of bodies which they actuate, so as to impair and finally to subdue its cohesive force; whence the phenomena of softness, brittleness, fluidity, and vaporisation will arise. All the undulations included between the extremes of one sixty thousandth of an inch for the violet rays, and one forty thousandth of an inch for the red, are visible, that is, they are capable of exciting vibrations in the optic nerve; those which are less than one sixty thousandth can excite chemical effects, and those which are greater than one forty thousandth can excite heating effects, though they cause no sensation of light in the human eye.

It is probable, says Dr. Young, that light and heat occur to us, each in two predicaments, the vibratory or permanent, and the undulatory or transient state; vibratory light being the minute motion of ignited bodies, or of solar phosphori, and undulatory or radiant light, the motion of the ethereal medium excited by these vibrations. Vibratory heat is a motion to which *all* material substances are liable, and which is more or less permanent; and undulatory heat is that motion of the same ethereal medium which has been shown by Pictet and Herschel to be capable of reflection and separate refraction, like common light. Newton entertained the same sentiments. He regarded heat as

consisting in a minute vibratory motion of the particles of bodies; a motion communicable through an apparent vacuum, by the undulations of an elastic medium, which is also concerned in the phenomena of light. Such vibrations may be excited among the molecules of bodies, by percussion, friction, and the internal motions of matter which accompany, and probably constitute, its chemical changes. But the particles of fluids which cannot be heated by the most violent mechanical friction or percussion, seem to possess hardly any power of imparting heat to one another; showing apparently some analogy between the communication of heat, and its mechanical excitation.

The syllogistic division of the sunbeam into three orders of particles, the calorific, colorific, and the chemical, is incompatible with the beautiful optical experiment of M. Arago, related at the end of the next chapter, where we shall see that by doubling the rays of light, their usual chemical effect on muriate of silver becomes null. Surely our chemical compilers who introduced that verbal distinction, will not venture to maintain that chemical rays, added to chemical rays, produce unchemical rays; which is, however, the necessary consequence of their hypothesis.

That heat consists in such vibrations, seems to be demonstrated by a fine experiment made long ago, by Sir H. Davy; in which two pieces of ice were converted into water, by their mutual attrition, in an atmosphere at the freezing temperature. Now, since the specific heat of water is much supe-

rior to that of ice, no such cavil can be offered to that experiment, as was urged (however unjustly) against Count Rumford's similar deduction from the heat evolved in the boring of cannon. Montgolfier furnished a fact very favourable to the undulatory theory, when he showed that a piece of ordnance, whether old or new, becomes much more speedily heated by discharges, than if it were filled with burning coals, for ten times the period of the explosions of the gun-powder. The intense and durable ignition of a platinum wire, placed under the electric influence, seems explicable also only on the same principles.

In Sir H. Davy's experiment, since the heat requisite for converting ice into water, could not be derived from the surrounding cold medium, nor from the body itself, whose capacity is low, there is no alternative, but to conclude, that heat must be actually generated by friction; and since it was in that case generated out of nothing, it cannot be any thing material; nor even an entity, immaterial or semi-material, if such language may be used. It must, therefore, be a quality; and this quality can only be motion; a deduction quite conformable to the sentiment of Newton. We may hence understand why both heat and light come to possess analogies with sound. Thus a magnetic steel bar set a ringing for some time, will be deprived of its magnetism as perfectly as if it had been heated red hot; and a charged electrical jar may be discharged equally by heat and by causing it to sound like a musical glass.

The great physico-geometers of France, MM. Fresnel, Poisson, Arago, and Fourier, now contemplate light and heat as modifications of the same power. A skilful mathematical analysis has satisfied them, that the equations of the propagation of heat in solid bodies may be conciliated, with the equations of the undulatory movements of an eminently elastic fluid. The propagation of the temperature of the molecules of a body cannot indeed be assimilated to a fluid current, or to the regular propagation of waves in an elastic medium. These molecules acquire, on the contrary, their proper temperature, that is to say, vibrations which continue after the passage of the calorific waves, only in virtue of the portion of their movement which is not regularly propagated.

When the brute quiescent mass is pervaded by this vibratory motion, its particles necessarily renounce their contact, and being at liberty to move through a greater or less space, assume such forms as the equilibrium of the attractive and calorific power demands. Fluidity, or absolute incoherence of the particles, is not indispensable for their changing the position of their attractive poles, and being grouped in new arrangements. Thus, if a mass of basalt be exposed to a high temperature, it will melt into a liquid glass, which quickly cooled remains a transparent and uniform vitreous body. Now if this body be heated again for some time, but so moderately as not even to have its substance softened, it will become throughout its whole interior a congeries of regular crystals.

When first the calorific energy was made to actuate the body of the earth a mighty change would ensue. The central mass composed, most probably, of the metallic bases of the earths and alkalis, as volcanic phenomena seem to attest, would fuse, the exterior parts would oxidize into the crust of mineral strata, and the outermost coat of all, the fixed ice, would melt into the moveable waters.

The infusion of this quickening energy, seems distinctly indicated by the inspired historian of the earth. "In the beginning, God created the heaven and the earth. And the earth was without form and void; and darkness was upon the face of the deep. *And the Spirit of God moved upon the face of the waters.*" This last idea, has been, perhaps, more truly rendered by Milton, in the expression, "dove-like sate brooding on the vast abyss, and made it pregnant." In this sublime conception, thus finely paraphrased, may we not recognise the impregnation of the torpid sphere, with elementary fire, that principle of all material activity; that power which loosens the bands of primordial cohesion, and communicates the essence of plastic mobility to a refractory solid? But for this marvellous constitution, as displayed especially in water, the face of nature would have for ever exhibited a death-like silence and a dread repose. The globe would have been cased in an unchanging and waveless ocean crust.

Many theorists have supposed the pre-existence or pre-creation of a chaos, of which the actual sun and planetary globes, were afterwards formed, either

at once by this mandate of Divine Wisdom, or by spontaneous developments through indefinite ages. But neither reason nor revelation warrants such suppositions. That the earth was constructed with reference to the accommodation of living beings at the volition of Omnipotence, will not be denied by any rational naturalist. It is difficult to imagine, therefore, what benefit, even theoretic cosmogony can derive from antedating the creation of a chaotic mass, any period of years, whether thousands or millions. We thereby merely approximate Creative might to the standard of human imbecility. Because the chemist must wait many days, perhaps months, before he can draw forth regular crystals of saline solids from his heterogeneous solutions, must the Deity be supposed to require indefinite ages, for crystallizing the granitic nucleus of the earth, and depositing over it, the shelving layers of gneiss and mica-slate? Herein the cosmogonist perfectly resembles the idolatrous savage, in ascribing to Deity, capacities and dispositions similar to those of his own foolish or malignant heart.

The Being who said "Let there be light, and there was light;" could also say, let the earth be formed, and its passive matter would instantly arrange itself, conformably to its destined purposes. The crystalline arrangement proceeds from the exercise of peculiar attractive forces, ordained by supreme wisdom to regulate the molecules of matter. Even man, by galvanic and other means, may greatly quicken the working of that plastic force; and why should its instantaneous effectuation

be deemed beyond, or unworthy of, Divine Agency. Matter derives not only its existence, but its various properties, from God. At what period any district of the universe was brought into being, and what form was then assigned to it, we can learn only from extrinsic testimony. The primitive rocks of the practical Geologist contain within themselves no register of their birth-day. The theorist may indeed speculate on the order of priority in primordial rocks, and call them successive formations; but this order can be so little established by inductive evidence, that the oldest formation of Werner, his primitive granite, may be the newest, according to Hutton's views.

The Theistical Neptunists would have us believe that our globe existed in a chaotic state, since the epoch indefinitely remote, at which its materials were crudely congregated by Divine Agency. They further say that the same creative power endued its constituent parts with peculiar attractive and repulsive forces; and then they desire us to believe, that these forces were set in mutual conflict, through uncounted ages, for the purpose of eventually bringing order out of confusion, and producing the crystalline and stratiform arrangements, observed in the crust of the earth. Now, what is gained by granting these hypothetical premises? Nothing that I can apprehend. They merely serve to show the presumption of man, who regards the primitive structure of this terraqueous globe, a labour too intricate for the instantaneous fiat of Omnipotence.

Again, had our earth pre-existed from eternity, in chaotic confusion, as some cosmogonists have taught, in chaotic confusion it must have eternally remained. The regular order and subserviency of its parts, are irresistible proofs of an originating intelligence, which acting with unlimited power, needed not to wait the slow progress of precipitation from a chaotic fluid, for the production of our, or any other planetary spheroid. On this subject where sound reason must apply the principles of corpuscular science, the sentiments of Newton merit the deepest attention. "It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportions to space, as most conduced to the end for which he formed them. All material things seem to have been composed of the hard and solid particles above mentioned, variously associated in *the first creation* by the counsels of an *intelligent agent.* For it became him who created them, to set them in order; and if he did so, it is unphilosophical to seek for any other origin of this world, or to pretend that it might rise out of a *chaos* by the mere laws of Nature; though being once formed, it may continue by those laws for many ages."* By Nature Newton means here, the series of laws imposed on matter by its Author.

Many speculative writers have considered the

* Optics, Book III., towards the conclusion.

record of Moses as referring merely to the origin of the human race, without at all defining the epoch at which either the earth or the system of the world was made. This opinion seems quite incompatible with the direct and obvious meaning of his narrative of Creation. The demiurgic week, as it is called, is manifestly composed of six working days like our own, and a day of rest, each of equal length, and therefore containing an evening and a morning, measured by a rotation of the earth round its axis. That this rotation did at no former period, differ materially in duration from the present length, has been shown by Laplace in his *Systeme du Monde*. Hence it is to be regretted that any commentators of Scripture, misled by the fancied necessity of certain geological schemes of stratiform superposition, should have vexed themselves and their readers, in torturing the Hebrew words for day, and evening and morning, into many mystical renderings. That Moses attached no such vague meaning to the creative days in Genesis, is evident from the language of the fourth commandment in Exodus. "Six days shalt thou labour and do all thy work, but the seventh is the Sabbath of the Lord thy God; in it thou shalt *not* do any work . . . for in six days the Lord made Heaven and Earth, the sea and all that in them is, and rested the seventh day: wherefore the Lord blessed the Sabbath-day and hallowed it." Here, as every where else, the Bible is its best interpreter, and will always enable any man of common sense and unbiassed judgment, to arrive at a satisfactory conclusion, while the dupe

of critical refinement is stumbling in a labyrinth of Hebrew roots.

We may, moreover, ask why we should claim in behalf of our globe, a more ancient origin than that assigned by the inspired chronologist? Will its rank, dignity, and importance, be enhanced by a remote genealogy? Is this a taint of the pride of ancestry, common to the whole family of man? But how can it be safely gratified? Even lynx-eyed science can pierce the dark veil of creation no further than common vision. Her telescopic glasses, which pierce farthest into space, have no time-penetrating power whatsoever.

That Geometry can carry the eye far into the future and the past, is a mere verbal fallacy. It can enable us to calculate the relative positions of spherical masses, revolving at certain rates in certain orbits for a series of ages; but it reveals nothing about the condition of these masses, in time past or future, far less as to their origin. Had we been told that Deity, in the beginning, created a chaos out of which symmetry was to be educed through a long series of material transmutations, then philosophy might have proffered her conjectures concerning the order of evolution; but ancient chaos is merely a mythological fiction, disavowed alike by the word and wisdom of God. The pristine reign of elemental strife and confusion under that "Anarch old" is inconsistent with the Government of Omnipotence. Chaos is, in fact, a dogma borrowed by Pythagoras from the Persian Magi, representing the eternal war that was waged between Ormuzd, and

Ahriman (Oromasdes, and Arimanius,) the uncreated principles of good and evil, of light and darkness. Had these two contending powers been equal, as they were diametrically opposite in every aim and effort, then reciprocal counteraction must have resulted, the equilibrium of Death. Thus nothing could be, for nothing would have been suffered to exist. It is marvellous how Doctors of Divinity dared to introduce the heathen and atheistical absurdity of a Chaos into their commentaries on the Mosaic record of Creation. With regard to the antiquity of our earth, nothing can be known except what the Eternal Spirit has deigned to reveal. *Itaque salutare admodum est, si mente sobria, fidei tantum dentur, que fidei sunt.*—Bacon.

The date of its creation, according to the Chronology of the Hebrew Bible, was 4004 years before the Birth of our Saviour. Astronomy shows that the great axis, or longest diameter of the elliptic orbit, in which our earth revolves round the Sun, as placed in one of the foci, coïncided at that epoch with the line of the equinoxes. Hence, then at the instant of the autumnal equinox, the sun was nearest the earth, or in perigee, and of the vernal equinox, he was in apogee; and therefore his elliptic orbit and time of revolution were each evenly divided between the seasons. From spring to autumn, as many days and hours elapsed, as from autumn to spring, for either hemisphere of our globe. Ever since that date, the summer division of the year has been growing longer, and the winter division shorter, for all latitudes north of the equator; the difference

of length amounting in the present century to more than seven days. From the equinox of spring, to the solstice of summer, 92 days, 21 hours and a half, intervene; from the summer solstice to the equinox of autumn, 93 days, 13 hours and a half; from this equinox, to the solstice of winter, 89 days, 16 hours and three quarters; and from this instant, to the vernal equinox, 89 days, 1 hour and 40 minutes. The summer section of the orbit contains, therefore, 186 days, and 11 hours, while the winter section contains only 178 days and 18 hours, the difference being no less than 7 days and 17 hours,—a difference to which, in some measure, the superior temperature of the northern terrestrial hemisphere may be ascribed.

Such was the position in which the earth was launched into space, such the attitude in which it commenced its circling career. I have no doubt, that by many it will be deemed the conception of a narrow mind, to limit the origin of our earth to so modern an epoch. But if it was formed for the dwelling place of Man, what use is there for imagining a more distant beginning? Why build a mansion in the wilderness of space, long ere tenants are prepared to occupy it? Nor are we warranted in ascribing an earlier date to the celestial orbs; for the heavens and the earth were the offspring of one creative mandate. And what advantage do Philosophers hope to gain, by going back a million of ages? Even then they are at an era equally recent, compared with Him who is from everlasting to everlasting, for with the eternity of HIS BEING, all revolv-

ing time is incommensurable. Though the existence of spiritual intelligences prior to the formation of Man, seems to be suggested in Scripture, yet of material pre-existence, no indication is given. It appears, therefore, that neither Reason nor Revelation will justify us in extending the origin of the material system, beyond 6000 years from our own days. The world then received its substance, form, and motions, from the volition of the Omnipotent.

Assuredly, no rational creature can carry its thoughts, without a profound sentiment of dismay and self-annihilation, into that infinity of time and space, which was occupied by Deity alone. Can Philosophy tranquillize the soul, in doubt, whether this appalling solitude shall not return? No indeed. But the Faith of Jesus Christ, founded on his Resurrection, gives his followers the assurance, that the future infinity will be of a different character from the past; for in it, the self-existing Jehovah, will live in fellowship with the spirits of just men made perfect.

That divine Revelation was not imparted to Man, for the purpose of instructing him in the recondite principles of Physics, is a proposition fully laid down in the Introduction. Yet there may be certain primary facts, beyond the horizon of science, shadowed out by prophecy, as limits to speculative temerity, and resting points to the pious spirit. Without such supplemental illumination, Man can know nothing of the cause, and manner, of himself, and his companion beings, coming into existence. Igno-

rant of these transcendent truths, the ancient Philosophers plunged themselves and their scholars into an ocean of doubt, and error. Notwithstanding the many beacons of their shipwrecks which shine in history, modern philosophers still disdain to consult the unerring oracles of God, on questions to which they alone can give a true response. In such matters, Science can hold no haughty pretensions, but must sit down a humble disciple, to learn the rudiments of all knowledge. Once imbued with these fundamental axioms, she may then safely advance in the kindred paths of observation and experiment; of calculation and induction. So far do the Sacred Scriptures bear on Physical research; and no farther. The Philosopher is thenceforward left to exercise his judgment on every object or event, level to his rational faculties. The paths of Religion and Science are subsequently distinct, though never opposite, each conducive, when rightly pursued, to the dignity and happiness of human nature. It is equally to be regretted, that this separation of the subjects has not been more carefully observed by the expositors of Revelation; and that the parallelism of aim in the study of Nature and its Author, has been too often disregarded by the Philosopher.

CHAP. II.—OF LIGHT.

Since the fluid condition of bodies is known to proceed from the vibratory actions of heat, counteracting more or less the cohesion of the attractive

poles of the particles of matter, we have humbly proposed to recognise, in the expression, "the Spirit of God moved upon the face of the waters," the commencement of the quickening energy, from which our globe derives all its mobile and vital capacities. Between heat and light, so intimate a relationship subsists, that they must be conceived as two modifications of the same fundamental agency. Thus, if any substance, even a stone, water, or air, be heated to a sufficient degree, it becomes luminous.

The light evolved so copiously from the bodies of dead fish, is extinguished at a freezing temperature; but shines forth again whenever they are thawed.

And on the other hand, the solar light is always accompanied with a calorific influence. This relationship appears in the narrative of Creation, for consentaneously with the movement of the Spirit upon the face of the waters, God said, Let there be Light, and there was Light.

The phenomena of light have generally been ascribed to the impulsion of certain material particles, supposed to be emitted in rapid succession, by luminous bodies constituting a nearly continuous chain, called a ray of light. So seriously has the reality of this notion been entertained, that some theorists have undertaken to determine the size, distance, velocity, and momentum of these particles, if not with absolute precision, at least within certain limits of the truth. Priestley relates some experiments of Mr. Mitchell's, made by throwing the focus of a concave mirror on the extremity of a very

delicate balance-beam nicely suspended, by which means, a slight motion being given to the beam, it was inferred that the light thus collected, had a sensible momentum. From the weight of the beam, and from the motion which was communicated to it by the impulse of light, also from the well known velocity of light, it was calculated, that the matter contained in the light which was thrown upon the end of the above-mentioned beam, during one second of time, and which was collected from a reflecting surface, of about 4 square feet, amounted to no more than one 1200 millionth part of a grain. But an uninterrupted sensation of vision, may be produced by a discontinuous series of impressions of the luminous particles; as a light rapidly moved across a hole in a dark screen, makes the hole appear constantly luminous. Therefore it was further computed, that a particle of light projected every tenth of a second from each point of a luminous surface, was sufficient for uninterrupted vision. But in one tenth of a second, light moves through twenty thousand miles; hence this may be the interval between the successive links in the luminous ray, permitting other particles to cross without chance of mutual obstruction. Another step led the same theorists to measure the waste of luminous matter, which the sun would experience in a day, a quantity which they found to amount to 2 grains; constituting only 670 pounds, avoirdupois, in 6000 years.

It is difficult to say, whether the above experiments or deductions are most absurd. A delicate balance, that for example made by Ramsden, for the

Royal Society, is so easily disturbed by heat, that the one arm will elongate and cause its scale to descend, when it receives the radiation of heat from the body of an experimenter, more directly than the other arm. Hence, by his moving a little to the right or to the left, in front of the beam, its truth will be impaired. Therefore, the heating influence of the sunbeam, on the air and the balance, in the experiments recorded in Priestley's History of Light, Period vi. Section 1. Chap. iii. was the proper and adequate cause of the elongation of the beam, and of the apparent weight of the luminous particles. In fact, of two closely corked globes of water accurately poised at the same temperature, in a delicate balance, if one be heated and replaced in the scale, it will preponderate by the elongation of its end of the beam. Neither these experiments, nor any other that I have seen described, justify us in concluding light to be an emission of material particles, however small. On the contrary, Dr. Thomas Young, Secretary of the Board of Longitude, has shown, by new experiments and researches, no less ingenious than precise, that light does not consist in the emanation of particles, but in the undulatory movements of a luminiferous ether, which pervades the Universe, rare and elastic in a high degree. He further shows, that this theory of the nature of light, long ago embraced by Huyghens, was at one time contemplated by Newton, with no unfavourable eye. "Were I," says Newton, "to assume an hypothesis, it should be this, if propounded more generally, so as not to determine what light is, further than that it is some-

thing or other capable of exciting vibrations in the ether; for thus it will become so general, and comprehensive of other hypotheses, as to leave little room for new ones to be invented. (Birch. iii. 249, Dec. 1675.)

When two undulations, from different origins, coincide either perfectly or very nearly in direction, their joint effect is a combination of the motions belonging to each. When they differ in frequency, they produce different colours, as the different frequency of aerial undulations, produces different musical tones. When two series of equal frequency coincide exactly in point of time, it is obvious that the united velocity of the particular motions must be greatest; and also, that it must be smallest, and if the undulations be of equal strength, *totally destroyed*, when the time of the greatest or forward motion, belonging to one undulation, coincides with that of the greatest retrograde motion of the other. In intermediate states, the joint undulation will be of intermediate strength. It is well known, that a similar cause produces, in sound, that effect which is called a beat in music; two series of aerial undulations of nearly equal magnitude, alternately cooperating, and destroying each other, according as they coincide more or less perfectly in the times of performing their respective motions.*

In a paper read before the Royal Society, July 1, 1802, Dr. Young laid down the following optical law; " that wherever two portions of the same light

* Dr. Young, Phil. Trans. Nov. 12, 1801.

arrive at the eye by different routes, either exactly or very nearly in the same direction, the light becomes most intense, when the difference of the routes is any multiple of a certain length, and least intense in the intermediate state of the interfering portions: and this length is different for light of different colours." This important law, the basis of a new and admirable theory of light, has been since fully adopted by M. Fresnel, and M. Arago, who have enforced and illustrated it by many fine researches. It demonstrates incontestibly the separate existence of a luminiferous ether, which may be made to undulate, not only by the sun and other permanent foci of vibration; but by a vast number of other causes, such as the friction or gentle heating of many mineral solids, and by several chemical actions, independent of combustion. Hence we see that this ether, being indispensable to the operation of every luciferous impulse, being in fact the substratum or subject matter of light, as air is of sound in general, must necessarily have had a precedent and independent existence, as Moses has declared in his narrative of creation. That luciferous impressions may be produced without any intercourse with the sun, is established by many facts. The phosphorescence of minerals buried since the origin of things in the bowels of the earth; the electric light caused by friction, metallic contact, or the volition of the electric eel; the luminousness of many insects, worms, and marine mollusca in the living state, and of the fibres of animals and vegetables, after death; the lucid points of the moon's disc, where the sunbeams

do not fall, all attest that light may exist without solar excitation. The luciferous action of dead fish may be transferred to water, may be brightened by adding a certain quantity of saline matter to the solution, darkened by a greater quantity, relumed by moderate dilution, and finally destroyed by heat or excess of water. It is very curious to see the luminous water, gradually becoming dim with the addition of salt, till the light finally disappears; and instantly bursting forth again from absolute darkness, by a certain dilution with water. Thus we may fill a wine glass with light. In all these cases, the luminous phenomena result from the vibratory impression communicated with greater or less force to the ethereous medium. These vibrations may be multiplied or diminished, by various causes, apparently very slight, and very enigmatical. In our further inquiries into the nature of light, we shall find that, if the length of a luminous undulation be less than one sixty thousandth of an inch, it becomes incapable of exciting the sensibility of our visual organs; but chemical experiments prove, that much shorter and more rapid undulations of the luminiferous ether exist beyond the luminous verge of the spectrum, which are still essentially light, though imperceptible to our visual orb. How unphilosophical therefore to infer, the absolute want or non-existence of light, whenever our purblind optics cannot discern it? And since we know that the luciferous ether may be thrown into *visible* luminous undulation, *without* the sun or stars, and into *invisible* luminous undulation *by* the sun and stars, what reason have we to

conclude that similar undulations do not agitate it, at all times independently of these focal excitants? Its elastic mobility indeed is such, that from the instant of its creation, or first disengagement from the primeval substance of the heavens and earth, its vibrations must have commenced, and have continued with more or less frequency and intensity to the present hour.

Had Moses written the record of Creation, from the informations of sense, or Egyptian learning, he would not have placed the Creation of Light, three days prior to the Creation of the Sun, Moon, and Stars. Accordingly, this apparent inversion of the order of natural causes and effects, this supposed anticipation of a phenomenon before the existence of its agent, has become a stumbling-block to many evil disposed minds, and a stone of offence to the impious, instead of being regarded as a motive to deeper study into Nature, and of humbler faith in its Author. When, however, in the progress of research, we come to discover that Moses has described events in their just order of sequence, an order, which reason could never suggest to him, and which has lain concealed till our own days, even from the philosopher, we are then forced to conclude, that he was inspired with a knowledge truly divine.

"Philosophy," says Frederick Schlegel, "when studied superficially, leads to unbelief and atheism, but when properly understood, is sure to produce veneration for God, and to render faith in him the ruling principle of our life."—*Lectures*, II. 168.

I shall now proceed to give a brief detail of the

experiments and observations subservient to the undulatory theory of light, a subject no less interesting on its account, than in reference to the primeval world.

Make a small hole in a window-shutter, and cover it with a bit of tin foil, having two parallel slits cut in it with a penknife, about one two hundredth of an inch asunder. When the room is darkened, the sunbeam in passing through these slits, will form an image, which received on a card, is seen to consist of a series of dark and brilliant lines, with coloured fringes. On closing one of the slits, the interior fringes disappear, although the light diffused in the shadow of the intermediate part of the other slit, be still perceptible. This experiment, due to Dr. Young, proves distinctly the mutual influence, or interference of the rays of light; but the following modification of it by M. Fresnel, affords a more striking result.

Introduce the sunbeam into a dark room, through a pin hole made in a bit of tin foil, or through a very small lens fixed in the window shutter. Receive this beam on a mirror consisting of two little pieces of plate glass, having their edges exactly in one line, in perfect contact, and very slightly inclined to each other. The deviation of the two from the same plane, should be as small as may be requisite to produce at once two images of the luminous point. They may be adjusted to the position, by pressing them down on a board, covered with soft wax, after their posterior surfaces have been blackened with China ink. The fringes formed after reflection,

present a series of brilliant and obscure bands, parallel, and equi-distant, which may be received either on a card, or viewed directly through a magnifying lens. The direction of these bands is always perpendicular to the straight line, which joins the two images of the luminous point, whatever be the direction of this line relatively to the touching edges of the mirrors; which proves that they do not proceed from any influence exercised by these edges on the luminous rays which pass in their vicinity. Besides, by increasing the angle of inclination of the mirrors, the two images of the luminous point may be separated to such a distance, that the rays which go to the formation of the fringes, shall be reflected so far from the touching edges, that we cannot reasonably suppose any sensible action to proceed from them.

The central band is brilliant, as in the fringes which divide the shadow of a narrow body placed in the sunbeam, or those obtained from the screen pierced with two narrow slits. That brilliant band is placed between two dark bands of the deepest black, provided a light sensibly homogeneous be employed, such as the red light received through certain red-stained glass. Each of these obscure bands is followed by a brilliant band, to which again succeeds an obscure band, and so in succession.

It is sufficient to compare the dark bands of the first, second, and third orders, caused by the joint reflection from the two mirrors, with the light reflected from a single mirror, in order to be convinced that the former are much less enlightened.

Hence, in the spaces which they occupy, it is plain that the addition of the rays of one mirror to those of another, instead of forming a more intense light, has *produced darkness.* It is easy to make this comparison, by contemplating successively the black bands, and the portions of the illuminated field, situated to the right and left of the portion doubly illuminated, where the fringes exist. It is thus perfectly proved, that in certain cases, *light added to light, produces darkness.* The preceding form of experiment removes all idea of *a diffractive* action, dilating the luminous beams in certain points, to condense them in others; since the phenomenon is here produced by rays regularly reflected.

It is obvious that the fringes result from the mutual action of the rays which meet each other; for if, with a screen, placed near one of the mirrors, we intercept all its rays, either before or after their reflection, these fringes disappear entirely, although the space which they occupied continues to be enlightened by the other mirror; and we no longer perceive any thing, except the pale and unequally distributed fringes which edge the shadow of the screen.

If we cover with the screen only one half of the mirror, so as to cause the disappearance of the fringes only over the half of their length, we can conveniently compare the remaining portion of the blackest of the dark bands, with the adjoining space, from which the light of one of the mirrors is intercepted by the screen, and thus satisfy ourselves that it is much more illuminated than the middle part of each of them, where, however, the whole rays reflected

by the two mirrors, come. Hence, these rays are neutralized in that place, by virtue of a certain action which they exercise on each other.

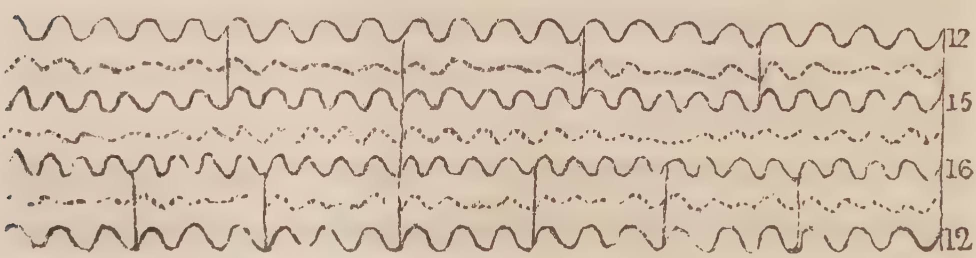
If we calculate the relative distances, from the hole in the screen, to the different bands, or the differences of the routes percurred by the rays which go to the production of each of the obscure and brilliant bands, we find, in the first place, that the middle of the brilliant band, which occupies the centre, corresponds to equal lengths of route. Calling *d*, the difference of the paths percurred by the rays which unite in the middle of the next brilliant band, either on the right hand or the left, then the middles of the other brilliant bands correspond to differences of routes, equal to $2\,d$, $3\,d$, $4\,d$, $5\,d$, $6\,d$, &c. whilst the middles of the obscure bands, from the most remote to those which accompany the central brilliant band, correspond successively to differences of paths percurred, equal to $\frac{1}{2}\,d$, $\frac{3}{2}\,d$, $\frac{5}{2}\,d$, $\frac{7}{2}\,d$, &c. The distances between these bands may be measured exactly by a micrometer microscope, such as is employed for reading off, and subdividing the graduated limb of an astronomical quadrant or circle.

It therefore results from these data that the union of rays from the two mirrors, produces the maximum of light, only when the differences of the paths that they have percurred is equal to $0\,d$, $2\,d$, $3\,d$, $4\,d$, $5\,d$, &c.; and on the contrary, they are mutually neutralized *so as to cause darkness*, when that difference is equal to $\frac{1}{2}\,d$, $\frac{3}{2}\,d$, $\frac{5}{2}\,d$, $\frac{7}{2}\,d$, $\frac{9}{2}\,d$, $\frac{11}{2}\,d$, &c. Such is the general law

of the periodical influences which the luminous rays exercise on each other.*

When the two luminous beams have the same intensity, as in the experiment just described, the

* When two *sonorous* undulations of air, or aerial waves of sound, differ but little in frequency, they tend alternately to destroy, and to augment each other's force, in a double or even quadruple degree, so that the sound gradually increases and diminishes at equal intervals, in continued succession. This intension and remission constitutes a *beat.* It affords a very accurate mode of determining the proportional frequency of the vibrations, when the absolute number of one of them in a second is given; or the absolute number of both, when the proportion between the two is known; because the beats are usually slow enough to be counted, though the vibrations themselves, separately, can never be distinguished. Thus if one sound consisted of 100 vibrations in a second, and produced with another acuter sound, a single beat in every second, it is obvious that the second sound must consist of 101 vibrations in a second. Two portions of a similar chord equally stretched, or two simple pipes, of which the lengths are respectively 15, and 16, will produce a beat in 15 vibrations of the longer one; and if we count the number of beats in 15 seconds, we shall know the number of vibrations in one. The easiest way in practice, of procuring two such strings or pipes, is to tune them by a third one, so that they may be respectively 4-5ths and 3-4ths of its length; the vibrations of the third pipe in a second of time, will also be equal to the number of beats of the first two in 12 seconds. (*a*)



The uppermost and lowermost curves represent a series of vibrations, of which 12 occupy any given period of time, the third and sixth lines, are two series of which 15 and 16 occupy respectively the same time: the joint effect of each pair is shown by the dotted curves which are interposed between them, the middle one representing the effect denominated a beat in musical sound, analogous to the dark band in light.

(*a*) Young's Lectures, Vol. I. p. 390.

middle of the obscure bands presents a *total absence of light;* at least if the light be sufficiently homogeneous or simple; but as this is seldom perfectly the case, it happens that this inequality of lustre between the brilliant and dark bands, which is so prominent in the first fringes, diminishes gradually as we recede from the centre, and at a certain distance from it becomes insensible. The reason of this is very obvious, for the light employed, however simplified it may be, either by previous decomposition with a prism, or by transmission through a coloured glass, is still composed, to a certain degree, of heterogeneous rays, whose colour and other physical properties are very little different, but in which, however, the interval d has not exactly the same value or length. Hence it results that the brilliant and obscure bands, of which d determines the position, are not separated by the same intervals. In fact, the breadths of the fringes produced by the heterogeneous rays differ so much the less, as the light employed approaches more nearly to perfect homogeneity; but however small this difference is, we may conceive that being repeated a great number of times, it will eventually produce in the position of the fringes such a difference, that the brilliant bands of one species of rays will coincide with the dark bands of another, so that, at a sufficient distance from the central line, (which corresponds to equal paths,) the dark and brilliant bands of the different kinds of rays of light employed, will mutually efface each other by their mixture, and present an uniform tint.

The more simplified the light has previously been, the more remote from the centre is the point where this perfect compensation takes place, and of consequence, the more numerous are the fringes. When we employ white light, which is the most compound, the number of visible fringes is also the smallest possible, so that scarcely more than seven of them, can be distinguished on each side of the centre.

They exhibit the tints of coloured rings, the reason of which colours is absolutely the same. If the length *d* were the same for the rays of the different colours, then the breadth of their fringes, (that is the interval between the middles of two consecutive brilliant or obscure bands,) being also the same, there would be a perfect coincidence both of their darkest and their brightest points; and the different rays which compose white light being present every where in like proportions, would produce a series of black and white bands, containing no trace of coloration. But this is by no means the case. Since the breadth *d* varies greatly for the differently coloured rays, indeed almost in the proportion of one to two, from one extremity of the solar spectrum to the other, the breadth of their fringes varies in the same ratio, so that their obscure and brilliant bands can no longer fall on each other, but differ in position according to their distance from the middle line. Hence it must happen that the brilliant band of rays belonging to a certain colour, will correspond to the obscure band of rays of another colour, whence proceeds the predominance of the first, and the exclusion of the second. Thus

the fringes will present a succession of tints, varying in the ratio of the unequal proportions, in which are intermixed the different rays that compose white light.

The middle line of the central band is always white, because as it corresponds to a difference of paths equal to zero (o), it is at the maximum of brightness for every species of rays, whatever be the length of *d*. On each side of this white band, the light becomes gradually coloured. The colours are very vivid at the second fringe, as well as up to the third and fourth, but afterwards they become feeble, disappearing altogether about the eighth, in consequence of the complete mixture of the dark and brilliant bands of all the colours, which naturally produces an uniform white tint.

We shall now endeavour to show the cause of these curious phenomena. Every one may remark on throwing stones into a tranquil pool, that where two series of waves cross on its surface, there are points of meeting, where the water remains motionless, namely, when the two systems of waves have very nearly the same force ; while there are other points, where the waves are enlarged by their union. It is not difficult to assign the cause of this. The undulatory movement of the surface of the water, consists of vertical motions, which alternately raise and depress the liquid particles. Now, by the mere effect of the crossing of the waves, it happens that in certain points of meeting, one of the two waves carries with it an ascensional movement, whilst the other tends at the same instant to lower

the surface of the liquid. When the two impulsions are equal, the liquid can obey neither the one nor the other, and must remain in repose. On the contrary, however, in the points of meeting where the movements conspire, where they are in constant accordance, the liquid moved in the same direction by the two waves, rises or falls with a velocity equal to the sum of the two impulsions which it has received, or to the double of one of them, when the two waves are supposed to be of equal intensity. Between these two points of perfect accordance and complete opposition, which present, on the one hand, the maximum of the oscillation of the liquid, and the total absence of movement, there is an infinity of other intermediate points, where the undulatory equilibrium is effected with more or less precision, in proportion as they approach more nearly to a perfect accordance, or to a complete opposition between the two movements which meet together in that place.

The waves propagated in the interior of an *elastic* fluid, although very different in their nature, from the liquid waves just described, produce mechanical results, quite analogous in their *interferences*, whenever they communicate oscillatory movements to the particles of the fluid. In fact, these movements need only be oscillatory, or carry the particles alternately to and fro, in order that one series of waves be destroyed by another series of like intensity; for whenever the difference of route between the two groupes of waves shall be such for each point of the fluid, that the movements of the first

in the one direction, or forwards, shall correspond with the movements of the second in the opposite direction, or backwards, they will become mutually neutralised, provided they are of equal intensity, and the molecule of the ethereous fluid will continue in repose. This result always takes place, whatever in other respects may be the direction of the oscillatory movement, in reference to the direction in which the waves are propagated, provided that it be equal in the two systems of waves. Thus, for example, in the undulations which are formed on the surface of a liquid, the oscillation is vertical, while the waves are propagated horizontally, and of consequence, in a direction perpendicular to the first. In the waves of sound or light, on the contrary, the oscillatory movement is parallel to the direction of the propagation. And these waves, like the liquid ones, are subject to the above stated law of interference.

We have described in a general manner the waves which may be formed in the interior of a fluid mass. To acquire a precise idea of their mode of propagation, we must consider, that when the fluid has every way the same density and the same elasticity, the vibration produced in one point, must be propagated on all sides with the same velocity ; for this velocity of propagation (which must not be confounded with the absolute progressive velocity of the molecules) depends entirely on the density and elasticity of the fluid. It thence follows that all the points that have been made to vibrate at the same instant, will be distributed over a spherical

surface, having for its centre the origin of the disturbance. Thus these waves are spherical, whilst those observed at the surface of a liquid are simply circular.

The straight lines drawn from the vibration to the different points of this spherical surface are popularly called rays. These denote merely the directions in which the movement is propagated. This is what is meant both by *sonorous rays* or rays of sound in acoustics; and by *luminous rays*, in the system which ascribes the production of light to the vibrations of an universal fluid, styled *ether*.

The nature of the different elementary movements of which each wave is composed, depends on the nature of the different movements which compose the primary vibration. The most simple hypothesis we can make concerning the formation of luminous waves, is that the small oscillations of the particles of bodies which produce them, are analogous to those of a pendulum, slightly removed from its point of repose; for we are to conceive the particles of bodies, not as immoveably fixed in the positions which they occupy, but as suspended between forces which mutually balance each other in all directions. Now, whatever be the nature of the equal forces, which maintain the particles in this situation, so long as these particles are removed from their position of equilibrium, only by a very small quantity, relative to the sphere of activity of these forces, the accelerative power which tends to bring them back to it, and which thereby makes them oscillate backwards and forwards from the

point of equilibrium, may be regarded as sensibly proportional to the recession. This phenomenon falls precisely under the law of the minute oscillations of the pendulum, and in general of all kinds of small oscillations.

Let us imagine, hung up in the elastic fluid, a little solid plane, which having been removed from its primitive position is brought back to it, by a force proportional to the displacement. At the beginning of its movement, the accelerative force can impress upon it only an infinitely small velocity; but its action continuing, the effects accumulate, and the velocity of the solid plane progressively increases, till the moment of its arrival at the position of equilibrium, where it would remain were it not for its acquired velocity; but in virtue of this velocity, it goes beyond the point of equilibrium. The same force which tends to recall it, and which now acts in a direction contrary to the acquired movement, diminishes continually the velocity till it be reduced to zero. Its elastic power continuing to act produces a velocity in a contrary direction, which restores the particle to its position of equilibrium. This velocity nearly null at the beginning of the return, grows greater by the same degrees as it had diminished, till the instant when the particle arrives at the point of equilibrium, which it passes in consequence of the movement acquired. On departing, however, from this point, the movement diminishes incessantly by the effect of the force which tends to restore the particle to it; and its velocity is once more reduced to zero, as soon

as it reaches its point of departure. It then recommences, with the same stages, the movements just described, and would thus continue to oscillate indefinitely like a pendulum, but for the resistance of the surrounding fluid, whose inertia progressively lessens the amplitude of its oscillations, and eventually extinguishes them altogether, at the expiration of a longer or a shorter time.

To fix our ideas, let us assume the instant when the solid plane has returned to its point of departure, after having executed two oscillations in opposite directions. Then the velocity which it had at the first moment, and which was sensibly null, is at the instant under consideration, transmitted to a section of the fluid distant from the centre of disturbance, by a quantity which we shall represent by *d*. Immediately, thereafter, the velocity of the solid plane, which has augmented a little, is communicated to the section in contact; from this, it passes successively through all the following sections, and at the moment when the first disturbance arrives at the section situated at the distance *d*, the second arrives at the immediately preceding section. Continuing thus to divide mentally, the duration of the two oscillations of the solid plane, into an infinity of small intervals of time, and the fluid comprised in the length *d*, into a like number of corresponding sections infinitely thin, it is easy to see, by the same reasoning, that the different velocities of the moveable plane at each of these instants is now distributed in the corresponding sections; and that thus, for example, the velo-

city with which the solid plane was animated in the middle of the first oscillation, (equal to $\frac{1}{4}$ *d* from the starting point,) must have arrived at the instant under consideration at the distance $\frac{3}{4}$ *d*. It is therefore the stratum placed at this distance, which is now actuated with the maximum of velocity in advance. In like manner when the plane has arrived at the limit of its first oscillation, its velocity was null, and this absence of motion must coexist in the section situated at the distance $\frac{1}{2}$ *d*, *d* being the whole breadth of the waves percurred during a forward and backward oscillation of the above imaginary plane. By its second oscillation, the plane retracing its steps, must give to the section of fluid in contact, and successively to the others, movements contrary to those of the first oscillation ; for when the plane retires, the section in contact pressed against this plane by the elasticity or the expansive force of the fluid, necessarily follows it, and fills up the void which its retrograde motion tends to produce. For the same reason, the succeeding section, is drawn towards the first, the third towards the second, and thus in succession. This is the manner in which the retrograde movement is communicated from point to point, till it reaches the most distant sections. Its propagation takes place according to the same law, as that of the forward movement. There is no difference except in the direction, or in mathematical language, in the *sign* of the velocities which they impress on the molecules of the fluid. The extent of fluid, moved by two oscillations of the solid

plane in opposite directions, has been called an entire *undulation*, and to each of its halves excited by these opposite oscillations, the name of *semi-undulation* has been given; of which the whole may be styled a *complete oscillation*, since it comprises the return of the vibrating plane to the point of departure. We see that the two demi-undulations which compose the complete undulation, present in the fluid sections which they embrace, velocities absolutely equal as to magnitude, but which are of contrary signs, that is to say, which carry the molecules of the fluid in opposite directions. These velocities are at their maximum in the middle of each of these semi-undulations, and decrease gradually to their extremities, where they fall to zero. Thus the points of repose and of greatest positive or negative velocity, are separated by intervals of a quarter undulation.

The length *d* of an undulation depends on two things: 1. On the promptitude with which the movement is propagated in the fluid; 2. On the time of the complete oscillation of the vibrating plane; for the longer its duration, and the more rapid the propagation of the motion, the farther will the first disturbance extend from the solid plane at the moment when this returns to its point of departure. If the undulations are performed in the same medium, the promptitude of the propagation remaining the same, the length of the undulations will be proportional to the time of the oscillations of the vibrating particles that give them birth. While the vibrating particles continue subject to

the same forces, the laws of mechanics demonstrate that each of their small oscillations has always the same duration, whatever may be its amplitude. Thus the correspondent oscillations will have in this case, the same length; they will differ merely by the greater or less energy of the oscillations of the fluid sections, whose amplitude will be proportional to that of the oscillations of the illuminating particles; for we see, from what has been stated, that each section of the fluid repeats all the movements of the vibrating molecule. The greater or less amplitude of the oscillations of the sections of the fluid, determines the degree of absolute velocity with which they move, and of consequence the *energy*, but not the *nature* of the sensation, which must depend, according to every analogy, on the *time* of these oscillations. It is thus that the nature of the sounds which the air transmits to our ear depends solely on the time of each of the oscillations performed by the air, or by the sonorous body, which sets it a vibrating; and that the greater or less amplitude, or energy of these oscillations, does nothing more than augment or diminish the intensity of the sound, without changing its nature, namely, its *pitch* or *tone*.

The intensity of light, therefore, will depend on the intensity of the vibrations of the ether; and its nature, that is to say, the sensation of colour which it produces, will depend on the duration of each oscillation, or on the length of the undulation, since the one is proportional to the other.

On this principle, the intensity of light must decrease in the ratio of the square of the distance

from the luminous point. A regular and uninterrupted series of luminous undulations, is called a *system of undulations.*

The length of *d*, or one undulation, for red light, is one forty thousandth of an inch ; and for violet light, about one sixty-four thousandth ; and proportionally for the intermediate colours. From the prodigious rapidity of the luminous vibrations, it is natural to suppose, that the illuminating particles may execute a very great number of regular oscillations in each of the different mechanical circumstances, in which they are placed, during the combustion or incandescence of the luminous body, although these variable circumstances succeed each other undoubtedly with an extreme promptitude. The millionth part of a second is sufficient for the production of 545 thousand undulations of the yellow light. Hence the mechanical perturbations which derange the regular succession of the vibrations of the illuminating particles, or even change their nature, might be repeated at each thousandth of a second, as it could still perform in the intervals more than 500 millions of regular and consecutive undulations. This observation serves to determine the circumstances in which the interferences of the luminous waves can or cannot exhibit sensible effects to our eyes.

We have seen that every wave produced by an oscillatory movement, was composed of two semi-undulations, which impressed on the molecules of the fluid, velocities absolutely equal as to intensity, but opposite as to the sign or direction of the movement. Let us suppose, first of all, that two entire

waves, moving with the same sign, and in the same direction, differ by a semi-undulation in their march. They will now apply to each other only over the half of their length, or half the interval between the first and last point of the fluid set in motion. There will be an interference only between the second half of the wave furthest in advance, and the first half of the other. If these two half waves are of equal intensity, as they bring to the same points of the ether, directly opposite impulsions, they will be mutually neutralised, and the movement will be destroyed throughout this portion of the fluid; but the movement will subsist without alteration in the two other semi-undulations. Hence, only one half of the movement will be destroyed.

Let us now suppose that every one of these two waves which differ in their route by a semi-undulation, is preceded and followed by a great number of other similar waves; then instead of the interference of two insulated waves, we shall have to consider the interference of two systems of waves. Suppose them equal, both in the number of waves that they contain, and in their intensity. Since, by hypothesis, they differ by a semi-undulation in their pace, the half waves of the one which tend to propel the molecules of the ether forwards, coincide with the half waves of the other which tend to propel them backwards, and they are in equilibrium of force. Hence the movement will be destroyed through the whole extent of the two systems of waves, excepting the two extreme half waves, which escape from the interference. But as these form a very small portion of the systems of waves, we per-

ceive that almost the whole of the movement must be annihilated.

It is extremely probable that the single impulse of a luminous semi-undulation, or even of an entire undulation, is not sufficient to irritate the fibres of the optic nerves, just as a single sonorous wave cannot put in vibration the bodies which might vibrate to its unison. It is the succession of these waves, which, by the continual addition of their minute partial effects, causes the sonorous body finally to oscillate in a perceptible manner, just as the regular succession of very inconsiderable impulses eventually sets the heaviest bell a vibrating. On applying to vision this admitted principle, which is most natural, and most conformable to every analogy, we see that the two residuary half waves mentioned above cannot affect the retina in a sensible manner, and that the combination of these two systems of luminous waves, must therefore realise the state of complete darkness.

If we retard, by a semi-undulation, the one system of waves, which is already that quantity in arrear, the difference of pace being thus an entire undulation, the coincidence between the movements of the two groupes of waves will be restored, and the velocities of oscillation will become additive throughout all the points of their mutual superposition. The intensity of the light is now at its maximum, or is doubled.

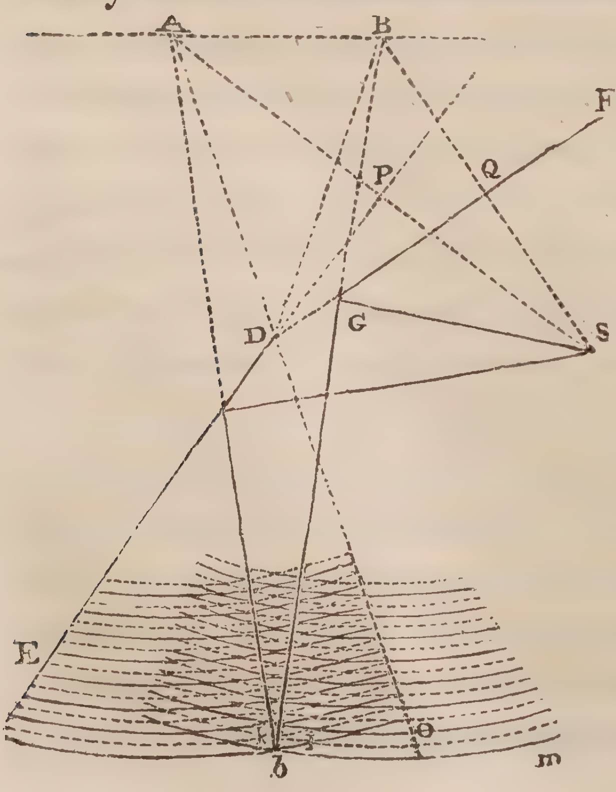
If we still retard by a semi-undulation the same system of waves, the difference of route being now an undulation and a half, we perceive that the super-position takes place between the half waves

of the two systems which occasion contrary movements, as in the first predicament, and that, consequently, all the waves of which they are composed must mutually neutralise each other, except the three half waves of each extremity, which escape from the interference. Thus almost the whole of the movement is still destroyed, and the union of the two beams of light must produce darkness, as in the first case.

By continuing to augment in succession, and by a semi-undulation at a time, the difference of march between the two systems of waves, we shall have alternately complete obscurity, and complete light carried to its maximum, according as the difference of pace shall be an even or an odd number of semi-oscillations. Such are the consequences of the principle of the interference of waves, which accord perfectly as we see with the law of the mutual influence of the luminous rays deduced from experiment; for the enunciation becomes absolutely the same, in calling *length of undulation* the difference of path percurred, a quantity which we have represented by *d*. Thus in admitting, as every thing leads us to conclude, that light consists in the vibrations of a subtile fluid, the period *d*, after which the same effects of interference are repeated, will be the *length of an undulation.*

The phenomenon of coloured rings, and that of the colours which polarised light developes in crystallised plates, present a particular case of interference, in which the waves of the two systems are parallel, and the dark bands are black. But, in the phenomena of diffraction, and in the experiment

of the two mirrors above described, the rays which interfere form always sensible, though very small angles with each other. In that case, the impulsions applied to the same points of the ether, by the two systems of waves, also cross under sensible angles; but on account of the smallness of these angles, the resultant of the two impulsions is almost exactly equal to their sum, when the impulsions act towards the same quarter; and equal to their difference when they act towards opposite quarters. Hence, in the points of accordance or discordance, the intensity of the light will be the same as if the two luminous beams had followed the same direction; for the most expert eye cannot perceive any difference. But if in reference to the intensities, the case of interference under review, resembles that first considered; in other respects it differs much from it, especially by the aspect which it presents, and by the circumstances necessary to its production.



The Figure represents a section of the two mirrors, and of the reflected waves, formed by a plane, drawn from the luminous point perpendicularly to these mirrors, projected in E D and D F. The luminous point is in S, and A and B represent the geometri-

cal positions of its two images. It is towards A and B, that the rays reflected from the first and second mirror are converged, according to the well known law of optics, that the angle of reflection is equal to the angle of incidence. To represent the two systems of reflected waves, we have described from the points A and B, as centres, two series of equi-distant arcs separated from each other, by an interval supposed to exhibit the length of a semi-undulation. For distinguishing the movements in contrary directions, we have traced in full lines, all the arcs of circles on which the ethereal particles are supposed to be impressed with the maximum of velocity in advance, at the instant under consideration; and we have dotted the lines on which the ethereal particles have the maximum velocity of retrocession. It follows, that the intersections of the circular dotted arcs with those in full lines, are the points of complete discordance, and consequently the middle line of the dark bands; and on the contrary, the intersections of the similar arcs give the points of perfect accordance. The crossings represent the successive positions or the trajectories of the middle of the obscure bands; and the trajectories of the middle of the brilliant bands.

We have been obliged to enlarge excessively, in the figure, the real length of the luminous waves, or distance between them, and to exaggerate the respective inclination of the two mirrors. Hence, we must not expect to find in it, an exact image of things, but only the means of representing to our

eye the interferences among the waves, which cross under a sensible angle.

It is obvious, from the simplest geometrical considerations, that the *breadth* of these fringes or luminous waves is in the inverse ratio of the magnitude of the angle, formed by the two interfering beams, and that the interval comprised between the middle of two consecutive obscure, or brilliant bands, is equal to the length of an undulation, *d*, divided by the sine of the angle under which the rays cross.

The mere inspection of the figure shows why it is necessary, that the two mirrors should be almost in the same plane, when we wish to obtain fringes of a somewhat perceptible breadth. In the small triangle *b n i*, the side *b i*, which represents the length of a semi-undulation, being almost one fifty thousandth of an inch for the yellow rays, the side *b n* which measures the half breadth of a fringe, becomes more perceptible, in proportion as *b n* has a smaller inclination to *i n*, because, in that case, their point of intersection recedes from *i b*.

The theory of undulations has explained the elementary facts, and most general properties of light, and has moreover furnished the means of representing optical laws by analytic expressions. For calculating the very various phenomena of diffraction; of the coloured rings produced by a thin plate of air, water, or other refracting medium; refraction itself, in which the ratio of the sine of incidence to the sine of the refracted rays, is precisely that of the lengths of the undulations

in the two mediums; the colours and the singular modes of polarisation which crystallised plates present; it is sufficient to know the different lengths of the undulations of the light in the mediums which it traverses, this being the only quantity which need be borrowed from experiment, and it is the basis of all the formulæ. If we consider these intimate and multiplied relations, which the theory of undulations establishes among the most different phenomena, we must be struck at once with its simplicity, and its fruitfulness, and allow, that even though it did not possess the advantage of explaining several facts absolutely inconceivable and unaccountable on the system of emission, it would merit the preference by the means which it affords of connecting together all the phenomena of optics, and embracing them in general formulæ.

The phenomenon of the dark bands produced in the beautiful experiment of the beam of light reflected from two mirrors slightly inclined to each other, seems of itself to be quite decisive against the emission of material particles from luminous bodies, for it is impossible that the accumulation and condensation of such particles, or that *light added to light* should produce darkness. Addition ought, in all circumstances of emission, to increase more or less the vivacity of the light, and in the above experiment of the double reflection from two mirrors, to double it. Before quitting the subject of light, I shall describe an experiment, which M. Arago showed me some years ago, in the

Royal Observatory of Paris. It brings a very striking accession of evidence to the undulatory theory.

It has been long known to chemists, that the chloride of silver becomes instantly black in the sunbeam, but retains its snow white colour for any length of time when kept in a dark place. On causing to fall on newly-prepared chloride of silver, the fringes produced by the interference of two beams reflected from the above described slightly inclined mirrors, they were observed to trace on it equidistant black lines, separated by white intervals.

This proves, that the chemical influence of the luminous rays is modified by their interference, like their optical properties, and that it varies in intensity according to the differences of the paths percurred. When this difference is equal to an entire number of undulations, the two systems of waves are in perfect accordance, and their vibrations have the greatest energy possible. In this case, their chemical effects ought to reach their *maximum;* and on the other hand, in the points where the difference of the paths percurred is an odd number of semi-undulations, the discordance being complete, the chemical effects ought to be null, like the sensation of light which the same points produce on the eye. These interesting positions have been confirmed by experiment. M. Arago further proved, that the unequal action of the light at the different points of the space where the two beams are united, depends on their mutual influence, for on withdrawing one of the beams, the chloride of silver assumes an uniform dark tint in the very same

space, in which lines alternately black and white were formed, when the two sunbeams arrived there simultaneously. In the same way it was demonstrated, that in the points corresponding to the differences of paths percurred equal to an odd number of semi-undulations, the chemical action of light is insensible when the two reflected beams arrive there together, whilst it re-appears when one of the beams is intercepted. This fact, *independently of all theory*, overturns the hypothesis adopted by several philosophers, according to which the chemical effects of light result from the combination of its matter with bodies; for if it were so, the effect produced would be greater the more considerable the quantity of luminous particles, and in no case assuredly could the chemical effect of light be increased by withdrawing a portion of the incident rays.

When the two beams are reflected by two mirrors, forming a *sensible* angle with one another, it happens that the same rays which lose in one point their luminous and chemical properties, by their complete discordance with the rays which they there encounter, find themselves a little farther on in different circumstances, and recover these properties. This shows, as M. Arago justly remarks, that they did not mutually destroy each other, but were merely neutralised for the moment, in the spot where their movements towards opposite quarters counterbalanced their vibrations. This play of interferences will be understood by inspecting the previous figure, p. 44.

The facts now detailed are amply sufficient to prove, that not only mere space, but that even the dense forms of matter are pervaded by a luminiferous medium, by whose undulatory movements the phenomena of light are produced. To the creation of this marvellous essence, the Divine mandate, Let there be Light, seems to refer. Its pre-existence was necessary to the luciferous functions of the sun, and the other foci of vibration. As we know that its undulations may be excited by many causes independent of the sun, we can find no difficulty in conceiving that alternations of light and darkness, constituting the evening and the morning of the first three days of creation, might have taken place. A far more vivid excitation of the luminiferous ether no doubt commenced when the solar globes were invested on the fourth day with their phosphoric atmospheres, to which most gratuitously a state of igneous combustion has been ascribed. This is a process of waste and change, unlike the frugal economy observed in the domains of Nature. What brilliant radiations may be produced by transmitting the influence of a voltaic battery through a bit of charcoal, placed in vacuo, yet the carbonaceous matter is not consumed! This light vies with the sun, but is certainly not borrowed from his beams. How, therefore, should purblind sciolists dare to cavil at the Hebrew prophet for recording in the sublimest language, that light, the first-born offspring of heaven, enlivened the wilderness of space before certain ponderous and inert spheroids were ordained

to modify its operations! As justly might they assert that the electric power, whether substance or quality, did not exist till philosophy mounted its cylinder, to excite luminous phenomena.

CHAP. III.—THE ATMOSPHERE.

The rare elastic medium which envelopes the earth, extending to an unknown, but not unlimited distance from its surface, is called the Atmosphere. As it exercises no observable action on the rays of light, at a greater elevation above the earth, than 45 miles, this height has been regarded practically as the atmospheric boundary. Experiment joined to calculation shows, that the density of the air diminishes in a geometrical progression; such as 2, 4, 8, 16, &c. while the distance from the earth increases in an arithmetical progression, such as 1, 2, 3, 4, &c. Thus it becomes known that the atmosphere, at an altitude of 7 miles, is 4 times rarer than at the surface of the earth, or contains only one-fourth of ponderable matter in the same bulk; and that it quadruples its rarity at every additional recedure of 7 miles; being 16 times rarer at 14 miles, 64 at 21, and so forth. Hence a cubic inch of air, such as we respire, would expand at the height of 45 miles into 9000 cubic inches; an attenuation 8 times greater than the best air pumps can produce.

The preceding computations are founded on the property which air, and other gaseous matter possesses, of accommodating its density to the incumbent pressure, and conversely of expanding its

volume by an innate elastic force, in proportion as the pressure is lightened. It is therefore the mutual resilience of the aerial particles themselves which causes them to escape from the receiver of an air pump, as we relieve them from atmospheric pressure by raising the piston; and not any active sucking force, which, by this instrument, we can exercise.

This curious constitution, scarcely recognisable in water and other liquids, fits the air for its numerous atmospheric functions. It becomes thus a springy yielding medium, though which the feeblest insect and largest bird may wing their way, with well adjusted buoyancy and speed; in which every form of pulmonary organ may find its appropriate exercise. As the elastic vehicle of sound, it is the medium of speech and music; thus enabling innumerable orders of animal beings to maintain the social intercourse prompted by their mutual wants and inclinations.

The dogmatists of Greece, and their scholastic followers, pronounced air, water, earth, and fire, to be the four elements, out of which every form of material being is composed. Experimental research has dissipated these illusions. Fire alone retains with the chemist, any pretensions to elementary rank, and even these are untenable. Air is by no means simple in constitution, but complex, in subserviency to its manifold functions. It consists, in the first place, of two main constituent principles, azote and oxygen, which are blended in the proportion of 79 measures of the first, and 21 of the

second. In 1000 parts, moreover, one part of carbonic acid gas may be reckoned. Each of these constituents has specific duties to perform, towards animate and inanimate nature. Thus the seemingly inactive azote, dilutes the oxygen to a proper pitch for respiration and combustion. Did the latter element act alone, it would make animal existence a short-lived fever, and every fire a furnace, in which not merely common fuel, but even metals would burn. The active uses of azote, in this scene of being, are as yet but imperfectly explored. The substance of all animal bodies is replete with it, in a concrete state; and yet we cannot tell by what channel, or from what source, it is introduced. In the food of the elephant, the horse, and the ox, science has not hitherto discovered the origin of that vast quantity of the azotic element, which is hourly assimilated to the solid and liquid texture of their bodies, to repair what is daily wasted and thrown off in excrementitious matter.

In viewing the atmosphere, as consisting of oxygen and azote, we cannot help remarking the delicate equilibrium of chemical proportions on which the well-being of organic life, and even the whole aspect of Nature, depend. Were the proportion of the oxygen or vital air diminished, breathing would be laborious, every warm-blooded animal would become asthmatic, and coal would not cheer the domestic hearth. On the other hand, were the proportion of the vital ingredient doubled, that is, instead of 1 of it to 4 of azote, as at present, were there 2 to 4, the temperate breath of heaven might

suddenly change into an atmosphere of intoxicating gas; for these are the chemical proportions, and sole constituents of this curious air. Were the bulk of oxygen quadrupled, so that its quantity should equal that of the azote, a most noxious air called nitrous gas (deutoxide of azote) might result; a gas which, with an additional charge of oxygen, would condense into an ocean of Aqua Fortis, or Nitric Acid. A slight modification of chemical affinity, would convert even our existing atmosphere into the most corrosive of liquids; a result which the Hon. Mr. Cavendish many years ago produced, by merely transmitting electric explosions through a small portion of common air. But science shows that the chemical equilibrium of the atmospheric elements, is fixed by the same Beneficent Wisdom, which confines the turbulent ocean, by an apparently slender barrier of sand.

The atmosphere contains another constituent of great importance, aqueous vapour, on which many of its most valuable properties depend. In raising this, it becomes the purifier of the ocean waves, and their distributor over the dry land, thence generating in the sky, clouds, rain, snow, hail, and dew, which by their deposition on the earth, give origin to fresh water springs, rivers, and lakes, all indispensable to the sustenance of animal and vegetable life. The contemplative author of the Book of Job was deeply affected with these meteoric wonders. "He bindeth up the waters in his thick clouds, and the cloud is not rent under them." Moses has accurately described this grand function of the atmosphere: "And God

said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were under the firmament, from the waters which were above the firmament; and it was so. And God called the firmament Heaven. And the evening and the morning were the second day."—*Genesis*, i. 6, 7, 8.

How perfectly does his order of elementary development accord with every principle of Natural Science! The most elastic medium, (called sometimes in popular language, the ethereal and imponderable element,) in which light, heat, and electricity seem to reside, first sprung forth; and next the weighty and less elastic fluids or gases were evolved. The Mosaic arrangement is in fact that now adopted by chemical philosophers.

Were the surface of the earth of uniform temperature throughout, and not chequered with water, the Atmosphere would every where be equal in height, density, and elasticity; but this density would necessarily decrease with the decreasing pressure, in proportion as the weight of the superior columns were removed, in a geometrical ratio to arithmetical heights, as already described. The average weight of the atmosphere is measured by a column of mercury 30 inches high; which column, an inch in area, weighs 14 pounds and seven-tenths. At the temperature of 32° F., mercury is 10500 times denser than air; therefore if 10500 be multiplied by 30 inches or $2\frac{1}{2}$ feet, the product 26250 feet will represent the height of a homogeneous

atmosphere, supposed of equal density above and below. But since the atmosphere is progressively attenuated, as it recedes from the earth, its temperature progressively sinks by its enlarged capacity for heat. The amount of this refrigeration is about one degree Fahr. for every hundred yards of ascent. And as the air contracts in volume, by decrease of temperature, the length of the superior columns will thus be diminished.

On the supposition of an unchanging temperature, the mercury of a barometer would fall from 30 inches to $20\frac{1}{2}$, by carrying it to the top of Ætna, or 10000 feet high; but in the actual predicament of an atmosphere condensed in the upper regions by cold, the equipoising mercurial column would fall to about 19 inches at the same elevation. If the surface of the earth acquire a higher temperature than that stated above, suppose 48°, the atmosphere will expand and be elongated throughout, so that on the top of Ætna, a greater weight of air will rest, so as to sustain the mercury there, at 19 inches and $\frac{1}{3}$. If the terrestrial temperature increase progressively from the poles to the equator, then the atmospheric altitude will also increase from the first to the second position, forming an inclined plane on its summit, instead of a curve concentric with our spheroid. Calling the thermometric degree 80 at the equator, and 0 at the poles, the barometer raised 10000 feet in the former region, will still be pressed by a residuary weight equal to 19 inches and fully $\frac{3}{4}$ of mercury; while in the latter, it will sustain only 18 inches and

about a half. In the circumpolar latitudes, the portion of the aerial columns near the surface of the earth, having a greater specific gravity, than the lower strata towards the tropics, will displace the latter, and cause a current towards the equator; but at greater elevations, the circumpolar atmosphere will be more attenuated, and will give way to the other, whence a counter-current towards the poles will ensue. Hence a perpetual circulation is maintained; the colder air in our hemisphere flowing southward below, and the warmer air northward above, thus tending to equalise the aerial temperature over the globe.

By the revolution of the earth on its axis, the various points of its surface move eastwards with a velocity proportional to their respective distances from the poles, where the motion is = 0. At the equator the velocity is 1037 miles per hour $= \frac{24896}{24}$; and at every degree distant from this circle, it may be found very nearly by multiplying the number 1037 by the cosine of the latitude. The atmosphere incumbent on any region, participates (when apparently at rest) in this eastward motion; and therefore the air over a northern circle of latitude, in passing towards a southern, retaining by inertia, its smaller velocity of rotation, will seem to linger, as it were, behind the aerial particles, among which it enters, and have the effect of a current from the west. Thus, also, by composition of motion, an impulsion towards the south-west will result, constituting what is called the trade wind. In the southern hemisphere, this wind will, for a

like reason, blow towards the north-west. The currents in the higher regions of the atmosphere in receding from their source at the equator, will tend to retain also by inertia their primitive velocity of rotation, and hence will strike the aerial particles among which they flow with a south-easterly impulse in the northern hemisphere, and a north-easterly in the southern. But getting cooled in their progress, they will become heavier and descend, checking to a certain degree the ex-polar currents below.

We must, moreover, consider the successive action of the sunbeams on the surface of the revolving sphere. By this cause, each meridian from east to west, has its incumbent stratum of air successively rarefied, so as to carry round a current with the apparent motion of the sun. The amount of this motion is to be added to the former. Navigators tell us that the trade winds in the Atlantic and Pacific Oceans, extend to about 28 or 30 degrees of latitude on each side of the Equator, within which limits, curious modifications from local causes occur.

In these trade winds, the higher clouds are very seldom, if ever, observed to move in the direction of the wind below, but usually in the opposite. On the top of the Peak of Teneriffe, the wind blows for the most part, so strongly from the south-west, that a person finds difficulty in standing upright, against the breeze.

We must now consider the gaseous influence which water would exercise.

Calling its elastic force, in round numbers, one-fifth of an inch at the freezing point of water, on the surface of the globe, then at a height of 30000 feet, its force would be one-tenth of an inch, corresponding to a constituent temperature of 15° F.; supposing no atmospheric air to exist. An increase of warmth upon the earth would give a higher constituent point for the vapour, and more water would, of course, rise in exhalation, but none would be deposited as long as there existed no inequality of temperature on the terrestrial surface. But with a decrease of heat from the equator to the poles, the water would rapidly distil from the hottest to the coldest place, by a constant ebullition in the former, as in the vacuum of an air pump, or in the exposed bulb of a Cryophorus. The equilibrium of the ocean would be maintained by refluent streams of water from the circumpolar regions.

Supposing the equatorial temperature 80°, the vapour would have then the corresponding tension of 1 inch, at the surface, and fully ½ at the height of 30,000 feet. Both its elastic force and specific gravity, are thus increased throughout the length of its column, giving rise to a pressure against the colder circumpolar columns. Since the elasticity of vapour increases nearly in a geometrical progression for equal increments of heat, the decrease of temperature in ascending in such a vaporous atmosphere, will be simply in an arithmetical progression. The diminution is very nearly three degrees, for every rise of 5000 feet.

Under these circumstances, the equatorial regions

would remain perfectly transparent, while rain would fall in every colder zone, in proportion to the densities at the respective places, and the decrease of temperature at the surface. Thus a circulation of vapour and water would be maintained, like the cohobation of the ancient chemists. Such would be the condition of an aqueous globe unprovided with a gaseous atmosphere, and unequably heated.

Let us next suppose that the heat in the upper regions diminishes (as happens from aerial rarefaction) more rapidly, than is due to the expansion of aqueous vapour alone. If the heat of the water on the surface of the sphere be 80° F. while at 5000 feet a temperature of 64½° prevails, " the water will have a tendency to throw off vapour of the same constituent heat as its own temperature; but the pressure above, being rendered too little by the influence of the forced degree of cold, to preserve the necessary elasticity below, the atmosphere will only possess the tension due to the lower degree; that is to say, the constituent temperature of the vapour will be only 67.9°. Evaporation must, therefore, ensue below, and its concomitant precipitation will take place above. The consequence of this situation of things must be, that a cloud will be formed at the height which has been named: for the atmosphere will be forced upwards by the nascent vapour below, and will be condensed at this point. The cloud, however, supposing the process to be sufficiently gradual, would not extend very far downwards, for the water during its pre-

cipitation, would be redissolved by the excess of heat in the lower regions, so that these might remain transparent and undisturbed. The temperature would be slowly equalized, and the balance of force restored. . . . The upper regions, upon this supposition, remain clear, for there the regular gradation is undisturbed."*

The simple case of a sudden decrease of heat at one stage of altitude in the atmosphere, by which condensation or cloud was produced, has been considered. We will next suppose that the rapid decrease of temperature continues throughout the column, nearly as happens in our atmospheric air, and that at the following stages of its height, the vapour is consequently forced to adapt itself to the following progression:

Height in feet,	0°	5000	10000	15000	20000	25000	30000
Temperature,	80°	64.4°	48.4°	31.4°	12.8°	—7.6°	—30.7°

The elasticity could not then exceed 0.043 of an inch upon the surface: the evaporation, if unobstructed by the inertia of the incumbent aerial particles, would consequently be excessive, and its force would almost amount to explosive violence; while the condensation above would be commensurate, precipitating the water in tornadoes. But the resistance opposed by the inertia of the atmospheric air, modifies these consequences in a singular manner. Thus the condensation takes place gradually, and at different heights; and the

* Daniell's Meteorol. Essays, 2d Ed. p. 57.

moisture falling gradually back into the excess of heat below, is converted into vapour of greater force, which pressing more upon the inferior strata, proportionately augments their densities.

The particles of aqueous vapour, in penetrating the interstices of the permanently elastic air, experience the same sort of retardation, as water does in percolating through the pores of sand. As soon as the equilibrium of air and vapour is thus attained, the mutual action ceases, and the particles of each press only upon those of their own kind. We may therefore contemplate the mixture, either as consisting of constituent particles in balanced repose, or seeking this state by means of intestine motion.

The following table of Mr. Daniell shows the small quantity of vapour, which could exist in an atmosphere of air, supposing it saturated with vapour throughout :—

Height.	Temperature.	Elasticity.
0	77°	0.910
5000	61	0.542
10000	45	0.316
15000	27.5	0.171
20000	9.3	0.088
25000	—11.0	0.042
30000	—35.0	0.016

The average quantity, therefore, of the vapour to this height could not exceed 0.297 $(=\frac{2085}{7})$ of an inch of barometric pressure, equal to 4 vertical inches of water, were it all precipitated at once on

the surface of the earth. We must no doubt consider that the altitude given above, comprises only two-thirds of the practical height of our atmosphere; the remaining third may, however, without any risk of error, be considered, from the lowness of its temperature, as totally free from water. Indeed, at 30,000 feet, the quantity is scarcely appreciable. Therefore the mean pressure, diffused through 45000 feet, would be reduced to about one-fifth of an inch, which would raise the barometer only from 30 inches to 30.2 in the atmosphere surrounding a sphere of the temperature of 77°, by a change from absolute dryness to perfect moisture.

The transition into cloud of the invisible aqueous vapour diffused in the air, occurs whenever the atmospheric temperature coincides with the dew point. This point may be most elegantly and precisely determined by Mr. Daniell's hygrometer. It appears from experiments with this instrument, that the elastic force of aqueous vapour does not diminish progressively with the progressive diminution of the temperature of the air, in its upper regions, but that the elasticity of the vapour continues nearly unimpaired through a great range of elevation, after which it suddenly encounters the dew point, and consequently a cloud is formed. If the vesicular water constituting this cloud, descends by gravity a very little way, it comes once more within the influence of a temperature higher than the dew point, and necessarily resumes the invisible condition. In this way, the under surface of the nebulous stratum becomes nearly concentric

with the surface of the subjacent plane. Above this first range of clouds, the dew point stands much lower, (the air being now stripped of much of its moisture,) and hence another considerable body of air must be passed through, before a temperature sufficiently low, be arrived at, to cause a second deposition of clouds. These must likewise be slighter than the first. We can thus readily understand the causes of the alternate strata of clouds and clear air, which often diversify the sky in serene weather. We may also comprehend how in stormy weather, a solitary cloud sometimes stands stationary over a mountain top, while myriads of other clouds drift past it with the gale. An observer on the summit, feels the vesicular particles of the seemingly fixed cloud, sweeping past him with great velocity, and discovers the stationary aspect which it exhibited below, to be illusory. The inferior beds of air, are relatively warmer, and moister. They dash against the sloping side of the mountain, are reflected up into the plane of condensation, where they give out their excess of water in the vesicular form. Above the cooling influence of the mountain top, the air is not depressed to the dew point of *its* constituent vapour, and hence it continues clear.

The dew point, however, often suddenly shifts, from a higher to a lower degree, and *vice versâ*, from causes ill-understood; most probably connected with electrical changes.

Had not a firmament of permanently elastic fluid been called into being, the aqueous vapours

rising from the sub-tropical seas would have flowed in constant torrents of fog towards the circumpolar regions, by a rapid distillation; the transfer being effected by a successive displacement of the intermediate rows of vaporous particles. Thus evaporation at the equator, communicating pneumatic pressure to that aqueous atmosphere, would induce speedy deposition of rain, over the arctic regions. By the creation of the air, however, a self-adjusting regulator has been introduced, to distribute the atmospheric waters in graduated quantities. The vapour thereby forced to wind its way amid the aerial particles, has to overcome considerable obstruction; and its progress of ascent is further checked by the coldness belonging to rarefied air. Hence, only partial nebulosities can take place in certain planes, with clear intervals; instead of a lurid canopy of cloud. Every person indeed must have remarked, that clouds are not always confined to one atmospheric level.

The aqueous particles are not suspended in the atmosphere by any power analogous to that of chemical solution. There is merely a mechanical mixture of particles in juxta-position, a state which most probably represents the mixture of oxygen, azote, and carbonic acid in the permanent atmosphere. Mr. Daniell has the following just remarks on this curious subject.

The constancy of the proportions, in which these gases are found to be combined in every situation, notwithstanding perpetual causes of disturbance, is the never failing theme of wonder. If we suppose a consumption of the oxygen to take place, by the

decomposition of the atmosphere, and carbonic acid added, as in the process of combustion, at any given spot, in what way is chemical affinity to act, so as to restore the uniformity of the compound? No new evolution of oxygen takes place, and it cannot be supplied by the contiguous portions; for we can never suppose the affinity of azote for oxygen to be satisfied, by the decomposition of an adjoining mass of azote and oxygen, held together by the same affinity. But, if the oxygen and azote be two distinct elastic atmospheres, as Mr. Dalton originally suggested, mutually permeating one another's interstices, the particles of each pressing only upon their fellows, and offering slight obstacles to the motions of the other sort, then a partial consumption of oxygen would be instantly supplied by a rush of this elastic fluid towards the spot where the equality of pressure had been disturbed. In fact, no sooner does a particle of oxygen quit the azote, and enter into a new combination, than the rows of particles by which it was pressed all around, speedily supply its place. The same reasoning may be applied to the carbonic acid, so profusely generated in combustion and respiration; for if not rapidly dispersed, a city would be uninhabitable in still weather.

The tension of vapour, which rises in evaporation, is determined, not by the temperature of the evaporating surface, but by the elastic force of the preexisting aqueous atmosphere. This proposition has been experimentally proved by Mr. Daniell, and Captain Sabine. While the sea breeze was blowing upon the coast of Africa, the hygrometer denoted the dew-point to be about 60°; but when the wind

blew strong from the land, it approached in its characters to a Harmattan; and the point of precipitation fell to the extraordinary depression of 37.5°; the temperature of the air being 66°. Hence we see, that notwithstanding the heat of the evaporating surfaces in the interior of that continent, the sands of its deserts yield so little vapour, that the air becomes parched.

As the quantity of vapour increases, the barometer generally falls, and again rises with its decrease; in the daily fluctuations of the weather. This fact is irreconcilable to the hypothesis which ascribes the rise and fall of the mercurial column to the greater or less amount of aqueous particles, and is in unison with that which attributes them to the unequal expansion of balancing currents of air, the main source of which is the fluctuation of the elastic vapour itself.

The dew-point, of which so much has been said, may be found for many purposes, by filling a tumbler with cold water, and noting its temperature at the instant, when in the progress of heating, it ceases to condense dew on its surface. To mark this instant with precision, requires close watching and frequent wiping with a towel; inconveniences from which Mr. Daniell's hygrometer is free. The higher the temperature at which dew continues to appear, the more moisture exists in the atmosphere; or the less the water needs to be cooled below the temperature of the air, in order to cause the dewy deposit, the greater chance there is of rain. When the dew appears on a glass, very slightly refrigerated, it is evident that the aqueous vapour in the

air is ready to come forth spontaneously. In this circumstance, should the temperature of the air sink a very few degrees, rain will inevitably fall. To what extent, however, it is more difficult to determine; for we often observe the air pouring down a heavy shower one moment, and so dry as to absorb moisture the next.

The earth is thus surrounded with two distinct atmospheres, mechanically mixed. The vapour or condensable elastic fluid, struggles to rise in a medium, whose heat decreases by expansion, at a much more rapid rate than its own; whence it is condensed in vesicular strata in the upper regions. Its latent heat is disengaged in the condensation, and imparted to the air; thus tending to temper the inequalities of the medium in which it moves, and to constrain it to its own law. This process must evidently disturb the equilibrium of the aerial fluid, by modifying its temperature and density. The system of atmospheric currents is also affected by the unequal expansion. The air at the surface of the globe is usually far from the term of aqueous saturation, in consequence of the condensing influence of the cold strata above. Thus the current of vapour which is constantly moving from the hotter to the colder regions, may pass from the equator to the poles, without producing that condensation in mass, which would otherwise have clouded the whole depth of the atmosphere, with precipitating moisture. The clouds are thereby confined to parallel and nearly horizontal planes, with intervening clear spaces. The mechanical influence of each fluid being proportional to

its elasticity, that of vapour compared with air, can never at most exceed the ratio of 1 to 30; so that the general character of the mixed atmosphere, is derived from the permanently elastic constituent. This controls and distributes the other by its movements. An important re-action, however, takes place. By gradual, but almost insensible expansions, the equipoised strata of the atmosphere are disturbed, storms arise, which agitate the mighty ocean, and prevent that stagnation of air and water, which would prove injurious to organic beings. But the disturbing forces contain the elements of counteraction; and the tempest soon exhausts its resources, and leads in a calm.—*Daniell's Essays.*

Thus we perceive, that the mechanism ordained by INFINITE WISDOM, "*to divide the waters which are under the firmament, from the waters which are above the firmament,*" is inferior to none of those refined and beautiful adaptations which lie most obvious to human sight, in the kingdoms of life, or in the starry heavens. But for this delicate adjustment of conflicting elements, the clouds and concrete vapours would have obscured the sky, to an indefinite distance, concealing for ever the glorious orbs which circulate in celestial space.

On a subject so transcendent and mysterious as the state of the new born atmosphere, it becomes not man to dogmatise. It is, therefore, in perfect humility, that I offer the following suggestions. No cause hitherto operated, that we can assign, why the sub-aqueous globe should possess any difference of temperature at its equator and poles. Even those who believe that the creation of light,

implies the creation of the sun, suppose that his beams could not penetrate to the terrestrial sphere on account of the dense vapours which still involved it. Mr. Daniell, in his 35th table, represents very faithfully, I believe, the condition of an atmosphere of air, to which vapour was admitted from a sphere of equal temperature covered with water. "A perpetual struggle," says he, "would ensue between the temperature due to the density of the air, and the constituent temperature of the vapour, accompanied by perpetual evaporation below, and simultaneous condensation above. No winds or lateral currents would be established, but an increasing circulation in a vertical direction."

On the gathering of the waters into one place, and the appearance of the dry land, the cause of the universal cloud which veiled nature being removed, its face should have been now cheered partially at least, with the sun's beam, had his orb been invested with luminiferous influence. But it was not so: for another day elapsed, before the Sun, Moon, and Stars, were set as lights in the firmament.

We cannot conclude this chapter, without adverting again to the philosophical precision with which Moses has defined the main function of the firmament—to separate the waters from the waters; ages before Philosophers had any idea of the mechanism of clouds. This has at length been happily developed by Mr. Daniell.

CHAP. IV.—PRIMEVAL LAND AND OCEAN.

Circumstances which will transpire in the progress of our researches, cause me to assign a different proportion between the dry and humid surface in the Primeval Globe, from that which now prevails. I am led to conclude, that the area of the land bore to that of the water, probably the ratio of equality, instead of nearly 100 to 365, as at present. One obvious consequence of this condition was, that the depth of the Primeval ocean was greater, as its superficial expanse was less. By this means, the water came into far deeper and more extensive contact with those ignited, combustible, and explosive materials, which the phenomena of mines and volcanoes, demonstrate to exist within the crust of the globe.

We learn from Physical Astronomy, that the only form compatible with an universal diffusion of waters round a revolving globe, is an oblate spheroid of certain dimensions. To the equilibrium of a fluid mass, thus diffused, it is necessary that any two columns reaching to the surface from any point within the fluid, should balance one another, or should press equally on that point. This equilibrium of the columns will take place in a mass of homogeneous fluid revolving round an axis, if it be formed into an oblate spheroid, such that the polar semi-axis is to the radius of the equator, as the attraction at the equator diminished by the centrifugal force at the same place, to the attraction at

the pole.* A homogeneous fluid of the same mean density with the earth, and revolving on an axis in the space of 23 hours 56′ 4″ of solar time, as it does, would be *in equilibrio*, if it had the figure of an oblate spheroid, of which the polar axis was to the equatorial diameter as 229 to 230. This is accordingly the figure which Newton gives to the earth. *Est igitur diameter terræ secundum equatorem, ad ipsius diametrum per polos, ut* 230 *ad* 229, Prin. L. iii. prop. 19. But if the mass, supposed to revolve on its axis, be not homogeneous, but be composed of strata that increase in density towards the centre; the figure of equilibrium will still be an elliptic spheroid, but of less oblateness, (less compressed at the poles,) than if it were homogeneous. This is the predicament more nearly of the earth, whose ellipticity is about $\frac{1}{312}$.

But there are actually considerable irregularities on the surface of the earth, so that the spheroid which agrees best with the degrees measured in France, is one having an ellipticity of $\frac{1}{152}$; nearly double of what may be accounted the mean ellipticity. These irregularities of shape consist in an unequal magnitude and density, of the great mountain masses and table lands, now standing above the waters.

But the form of the terrestrial ball was the regular spheroid, while it lay enveloped in the shoreless deep. "And God said, Let the waters under the heaven be gathered unto one place,

* Maclaurin's Fluxions, Vol. II. § 636—641.

and let the dry land appear. And it was so."—*Genesis*, i. 9.

In attempting to search into the secondary causes which may have been called into action, when the channel of the sea was hollowed out, and the mountains were upheaved from the abyss, it behoves us to walk with the most humble circumspection. A cosmogonist has said, "that man who has weighed the planets and measured their distances, may presume to trace the operations by which the surface of the globe was arranged." The reproach of presumption will indeed be incurred, if we do not travel closely in the inductive path. We must, above all, beware lest we be misled by such a vague analogy, as that offered in the preceding quotation. The diameters, densities, and movements, of the planets, are present objects of measurement, as we remarked in the Introduction. Man may accurately observe the whole series of changes through which they run, and from his observations, compute their weights and distances by a rigid geometry. But he was not permitted to witness the series of changes through which the materials of our earth have passed, in attaining their actual arrangement, and thus the Cosmogonist wants *data* of kindred certainty, with those possessed by the Astronomer.

Multiplied observations have shown, that the crust of the earth is composed superficially, or to a moderate depth of certain stratiform or schistose rocks, which being devoid of organic remains, are termed primitive. We shall at present confine our attention to two of them, called Gneiss and Mica-slate. These are arranged in planes usually parallel

to each other, the Mica-slate being, for the most part, uppermost. We have reason to believe, that hardly any district of the terrestrial surface is destitute of these great slaty rocks, though in many places they may be deeply covered over with secondary formations, and therefore inaccessible. Gneiss constitutes the body of the Himmalaya mountains, and abounds among the Andes, Alps, Urals, Pyrenees. It forms also Ross island, the most northern known land of the globe. Mica-slate is nearly co-extensive. But their wide-stretched foliated planes, are seldom or never horizontal, or concentric with the curvature of the earth. They usually lie at highly inclined angles, like tables resting on their edges, in a nearly vertical position. In very many localities, vast irregular masses of Granite, are seen rising up through the schistose fields, as if these had been upheaved and dislocated by its protrusion, and were thrown like mantles round its shoulders and base.

We therefore conclude that the primordial earth, as it lay beneath the circumfused abyss, was at first endowed with concentric coats of gneiss, mica-slate, and the other primitive schists; that at the recorded command of the Almighty, a general eruption and protrusion of the granitic, syenitic, porphyritic, and other unstratified rocks, took place, which broke up and elevated the schists into nearly vertical planes, similar to what now exist, leaving commensurate excavations for the basin of the sea.

In meditating on this mighty operation, though we may shrink from the overwhelming scene, and feel our faculties abased, nay annihilated as it were, in the presence of that Power, "who hath measured the

waters in the hollow of his hand, weighed the mountains in scales, and the hills in a balance; who sitteth upon the circle of the earth, and stretcheth out the heavens as a curtain," yet the magnitude of these terrestrial disruptions, will create no difficulty in the mind of the Astronomer, familiar with acts of Omnipotence incomparably more stupendous. Even the geographer would smile at the geologist, who should ask for Deity a countless lapse of ages to build up on the Earth its superficial scaffolding, whose size is to its total bulk, as the roughness of the rind, to the ball of the orange.

In treating of Primitive Formations, in the next chapter I shall adduce such evidence as will render the igneous origin of the unstratified rocks, more than probable, and demonstrate their agency in upheaving the schists, and causing the earth to deviate in many points of its surface, from its first form of a geometrical spheroid.

Before entering on these geological details, however, it will be right to consider the properties of water, and the creation of organic beings.

I. Water.—There are few things endowed with more marvellous properties, or which are less studied and understood, than water. The artist, indeed, appreciates its value in one respect, as an element of the picturesque, capable of giving life and splendour to the landscape. The lover of rural nature is also sensible of its charms; whether it murmurs in a brook, rolls in a foaming cataract, or expands into the silvery mirror of a lake. Hence the Painter and the Poet have vied with each other, to celebrate these emanations of creative kindness.

But higher and deeper thoughts than any which external beauty can suggest, fill the mind that contemplates the internal constitution of this Protean liquid. Though in mass it is incompressible, and able to burst a passage through the strongest metal or rock, yet its particles form a fluid assemblage, softer than ermine, and yielding to the lightest touch. Obedient to the laws of gravitation, it enjoys singular prerogatives. Each invisible atom presses solely for itself, neither giving nor receiving aid from its associates. It weighs, not only like solids, from above downwards, but laterally and upwards, with equivalent gravity. Possessed of perfect mobility, it never wearies in its journey, till it reaches the level plane of repose. Without shape, it is susceptible of every figure, and the parent of myriads of crystalline forms. Capable of being aggregated in an ocean mass, yet renouncing its cohesive attraction before the feeblest power, it becomes divisible into the rarest exhalation. It exerts at one time an impulsive force, nearly irresistible, before which even the mountain bows its head, and crumbles into dust; and at another, it gives way to the light canoe. Just dense enough to float the pine, and afford a buoyant highway for ships, it is rare enough to permit the fleetest motions of its finny tribes. Had it been more attenuated, it would not have served the navigator; and if either denser or rarer, in a very slight degree, fish could not have swam in it.

This water, by its mysterious tenuity, loosens the indurated soil, enters the invisible pores of plants, passes freely through all their vessels, expands in

the filmy blossom, and is an element of the fleeting aroma. But these fluid particles can be chained together in the firmest cohesion: in which state it may exhibit either the hardness of rock, or the softness of eider-down. Enormous blocks of water thus stand in immoveable columns, surmounting the loftiest pinnacles of our globe. How different are these from the soft insinuating liquid, which is the circulating medium of all organic life!

Let us now search still more minutely into the mystery of water. In its purest form, we view it as a compound of spherical atoms of oxygen and hydrogen, not confusedly blended, but joined in definite proportions; not placed in absolute contact, but closely adjoining each other by select points or poles of slight mutual attraction. Hence these all glide over one another, so as to pass through microscopic orifices, and recede at the least inequality of pressure. It is this constitution which makes its mass permeable to fish and floating bodies. The plain and vulgar element is now seen to be a most artificial assemblage of the bases of vital and inflammable airs; substances, in their insulated state, endowed with no plain or vulgar properties. Associated by chemical attraction with the element of coal, the three compose the concrete matter of the vegetable world, from the heart of the teak tree, to the essence of the rose. If into this triple alliance, be introduced azote, already spoken of as the main constituent of the atmosphere, that fourfold partnership will result, which constitutes the basis of all animal substance, whatever organic shape it may

assume, muscle, tendon, ligament, nerve, blood-vessel, horn, hair, brain, blood, or bile.

From this general account of the mystery of simple water, it appears, that a curious volume might be written on its mechanical and chemical functions. But as it exists in the ocean, it has a more complex nature, corresponding to its complex relations to different orders of being. It is imbued, first of all, with saline ingredients, which preserve its liquidity under latitudes, where the colds of winter would otherwise have congealed it. But for this impregnation, even Great Britain would have been what Iceland now is. It is the saline state alone, which fits it for the residence of many fish, which will not thrive in fresh water. Besides the substance usually called salt, it contains many other analogous compounds, all of which undoubtedly concur to beneficial purposes in the economy of Providence, though some of them be altogether undiscernible by man. It holds lime in the liquid combination of a muriate, and perhaps of a sulphate, from which the marine mollusca (shellfish) extract that earth, and condense it in the form of a carbonate, into their testaceous coverings. Whether the sea, from some of its unfathomed caves, replenishes itself with calcareous matter, in proportion as it is abstracted by shelly secretion, or whether it is growing less calcareous from year to year, are questions for future chemistry to decide. Geology leads us to believe that on the Mediterranean shores, calcareous organic formations have advanced with far greater vigour, at some remote

epoch, than at the present day. But as an equal activity now seems to prevail among the West India islands, and generally in the intertropical seas, the decline in European formation may most probably be ascribed to the refrigeration of climate, which we shall show to have been produced by the great catastrophe of the Deluge.

Sea water moreover contains a notable quantity of the magnesian earth in the state of muriate and sulphate, as well as muriates of potash and ammonia, and sulphate of soda, with several other substances, the uses of which in the ocean are still unknown.

Every common water in its natural state, whether salt or fresh, contains about a fortieth of its bulk of air, which it readily evolves either by the heat of ebullition, or when placed in vacuo. In these circumstances, we perceive minute globules oozing out from every point of the liquid, which when liberated, rise by their innate lightness and elasticity, in a pearly looking stream to the surface. Now this liquified air is the element of respiration, the *pabulum vitæ*, to all bronchial animals. The gills of fish elaborate that liquid air, as the lungs of land animals do its elastic form. Both organs convert its oxygenous part into carbonic acid, for the sustenance of vegetation, terrestrial or submarine.

Enough has now been stated to evince, that water in its liquid state is not the uninteresting inert element, which the multitude suppose it to be, but that its constitution is most refined and intentional, adapted to the manifold functions which it must discharge towards countless orders of organic and inorganic being. Its habitudes with heat are pecu-

liarly beautiful. A certain energy of this power gives to water its liquid condition, in which, as already mentioned, the molecular attraction is very nearly neutralised by the repulsive force. Had the cohesion of its parts been less, it could not have afforded the *reaction requisite* for the movements of fishes and ships; nor could man have availed himself of its impulsion to aid his feeble arm in preparing his food, clothing, and domestic accommodation. The same calorific agency wafts the ponderous liquid on the wings of the wind, to supply the organic inhabitants of mountains and plains with vivifying moisture; or under the guidance of mechanic genius, it animates the steam engine, the noblest offspring of science and art, the unwearied and docile servant of man.

The equilibrium of its mobility lies within narrow bounds. A very moderate reduction of temperature restores the cohesive power to uncontrolled dominion, under which the form of water ceases to exist, and might thus continue unknown. Again, had the particles of water been mutually elastic, though but in an inconsiderable degree, the least disturbance by winds or tides, must have produced tremendous commotions in its mass; and a floating body would have been alternately tossed into the air, and plunged into the depths, with destructive violence. Under such circumstances, the sea would have been an impassable gulf, between closely adjoining kingdoms, instead of being, as now, a thoroughfare between the most distant lands, the element of the noble art of navigation. By its almost inelastic and incompressible *crasis*, the body

of the ocean cannot resile, nor suffer agitation beyond a few fathoms from its surface, even from the force of the hurricane. In fine, the absolute passiveness of water, and independent gravitation of its parts, form its most valuable qualities.

On the third creative day, after the waters were gathered into their destined bed, the new-formed earth was forthwith clothed with vegetation, adorned "with herbs, and fruits, and forest trees." The instantaneous creation of the vegetable tribes, from "the herb yielding seed after his kind, to the tree yielding fruit, whose seed was in itself, after his kind," does not seem to have been made a stumbling-block by the Botanical student, as the first arrangement of the mineral strata, has been by the Geologist. Yet the cases are strictly parallel. Nay, whatever difficulty any imagination may have in conceiving the brute matter of the globe to have been arranged at once in crystalline and schistose masses, it ought to feel a much greater difficulty in conceiving the whole complex structure of a fruit or forest tree to be simultaneously produced from the root to the infloresence, with all the concentric layers of wood, alburnum, and bark, each composed of straight or tortuous fibres and tubes; and not formed, as we see them now, by progressive developement and growth. The creation of a perfect plant, the type and parent of an indefinite series, is far more wonderful to my apprehension, than the creation of an inert terraqueous spheroid. No Botanist or Zoologist, of sane reputation, inculcates that plants and animals acquired their perfect and unvarying forms, through successive organic depo-

sitions and catastrophes, as geognostic theorists have taught with regard to the primitive structure of the earth. What would be thought of a Naturalist who should pretend to determine the epoch of the world, at which the different layers of wood or bone were first formed out of some primordial chaos of vitality; when branches and limbs first began to sprout from simple trunks; when feathers, wool, and hair, first came forth for the protection of naked animals?

The third rotation of the terrestrial sphere, was accomplished amid a faint phosphorescence of the luminiferous ether. But towards its conclusion, a kingdom of life had been erected, which required a more vivid illumination. Accordingly the next revolution ushered in a golden dawn, the harbinger of the effulgent Day Star. Then the Sun was furnished with his phosphoric, or light exciting robe, a superficial luciferous film, which is probably the only peculiarity that distinguishes the structure of his body from that of his subject spheres. Created with the earth on the first day, when the law of universal gravitation was ordained to govern Heaven's isolated Orbs, he, with his brother stars, was not till the fourth,

> "Invested with bright rays, jocund to run
> His longitude through Heaven's high road."

Our ancient record of these events not only accords with every scientific principle; but intuitively defines the new function of measuring time which the orbs were fitted to perform, when they acquired their lucid exterior. "And God said, Let

there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days, and for years. And God made two great lights: the greater light to rule the day, and the lesser light to rule the night: he made the stars also."

The vegetable tribes bloomed for one day in unenjoyed beauty and fragrance. But with the next rising sun, two vast classes of animal life, with their varied susceptibilities of pleasure, were summoned into existence. The waters were replenished with all their orders of vitality, from the cold elementary mollusca, to the warm blooded whale. From this period, too, commenced that deposition of marine exuviæ on the ocean bed, which afterwards exposed to the eye of day by a mighty revulsion of the waters, have afforded to the fossil student, an exhaustless mine of observation. The winged inhabitants of the air were of coeval birth, and found abundant supplies prepared in the waters and the land, for their respective wants. The eagle now soared on adventurous wing round the naked granitic peaks, the albatross skimmed with unwearied flight the sparkling billow, and all the feathered songsters warbled in unison with the Divine benevolence.

Fishes and Fowls are classed together, as the creative work of the fifth day. Apparently these two orders of animals have little or nothing in common, and hence some sciolists have sneered at the collocation of Moses. But the true naturalist admires the scripture classification, because he perceives many fine analogies in it.

Flying modifies all the actions of birds, swimming

those of fishes. In these kindred qualities, both classes stand apart from quadrupeds, and the other land animals. Swimming and flying are, in truth, only the same act performed in different fluids. The effective instruments, organs, and movements, which produce or modify these acts, are similar or at least analogous. From this remarkable relation, we may expect to find many secondary analogies between the habits of fishes and birds. The wing of the bird, and the fin of the fish, differ much less from one another, than might be supposed at first sight; and hence the ancient Greek and Roman naturalists, as well as many in later times, have called them by the same name. Both present a considerable surface relatively to the size of the animal, which it may enlarge or diminish at pleasure. The fin, accommodates itself to these expansions and contractions, because it is composed like the wing, of a soft, flexible, membranous substance; and when it has received the size suited to the immediate want of the animal, it presents like the wing, a resisting surface, it acts with precision, it strikes with force, because, like the instrument of flying, it is stiffened with small cylinders, solid, hard, and nearly inflexible. Though unprovided with feathers, it is sometimes strengthened with scales, that possess the same texture as the feathers of a bird.

The weight of birds does not greatly exceed that of their own bulk of air; the density of fishes is very little different from water, especially that of the sea. Birds are furnished with an organization, which renders a great volume very light. Their lungs are largely developed; great air bags are

placed in the interior of their bodies; their bones are hollow and perforated, so as to receive with ease into their cavities the atmospheric fluid. Almost all fish have a peculiar bladder, which they can expand with air at pleasure, without adding sensibly to their weight.

The tail of birds serves as a rudder, and their wings are perfect oars. The back and belly fins of fish may be also compared to powers which regulate and direct, whilst the tail with its lengthened caudal fin, strikes the water, like an oar, and communicating impulsion to the animal, is the mainspring of all its rapid movements. We may therefore affirm that birds swim in the air, and fishes fly in the water. The atmosphere is the ocean of the first; and the sea that of the second. But fishes enjoy *their* domain, much more fully than birds; for they can traverse it in every direction;—rise to the very surface, sink into the abyss, or repose themselves in any part of the fluid itself.

The regular winds favour or modify the aerial voyages of birds; the currents of the ocean regulate in like manner the migration of its shoals. The instinct of generation, which can be satisfied only on coasts, constrains fish at each return of spring, to quit the deep ocean, and approach the shores. The females arrive first to deposit on the land-banks the burden of their spawn or eggs, and the males follow to fecundate them. Hence it is obvious, that fishes could not have animated the watery abyss, which circumfused the globe before the distinction of dry land and ocean existed. Thus we find the Mosaic statement, strictly accordant with

one of the most refined discoveries of Natural History. Wherever the land presents the greatest extent and variety of surface to the sea, there the fishes most abound. It is for this reason, that the great southern ocean is much more sparingly stocked with fish than our northern seas.*

The rural scene garnished with luxuriant herbage, was peopled in the beginning of the 6th day with its animal tribes, from the reptile to the elephant; and then Man, the lord of all the earth, was made in the image, and after the likeness of his Divine Creator. Endowed with the faculties and desires of celestial beings, and ordained to exercise a beneficent dominion over all terrestrial natures, he reflected visibly in his thoughts and actions, the Invisible Majesty of Heaven. How nobly does the sacred historian describe the excellence of the finished creation, which in its physical frame at least, has yet lost none of its original brightness, and is therefore equally fitted, as at first, to fill the contemplative mind with holy aspirations! All its parts display so clearly the work of an almighty hand, as to impress moral and religious sentiments, on every unperverted naturalist. "There is no speech nor language where their voice is not heard," pronouncing in reason's ear the primeval benediction. "And God saw every thing that he had made, and behold it was very good." "Then the morning stars sang together, and the sons of God shouted for joy."

The achievement of creation, by distinct and

* Lacepede.

independent acts, was performed on each of six successive days; demonstrating that it was not the result of a blind necessity, or a spontaneous, and therefore continuous, though irregular aggregation of chaotic atoms. It is thus kindly revealed, that the Deity operating with a sovereign liberty, directs his Almighty Fiat, where and when it seemeth good. As in making the world by his volition alone, he shows that nothing can resist his power, so in forming it, at several periods, he proves that he is the sole disposer of matter in all its modes of existence.

To the well being of man, the activity of his powers is essential. A lesson of daily industry is clearly inculcated in the recital of the six demiurgic or creative days; and a lesson of devout meditation is as plainly taught on the seventh, the day of rest, blessed and sanctified by God himself. By these alternate employments, bodily and intellectual, secular and religious, man, while obedient to his Heavenly Monitor, reached the highest perfection of his nature. His knowledge was co-extensive with his dominion; and charity was paramount over all. The properties of every terrestrial object seem to have been intuitively recognised. Thus when the subject animals passed with meek aspect in review before him, he discerned the nature of each, and denoted it by a significant appellation. "And whatsoever Adam called every living creature, that was the name thereof." The garden of Eden in all its luxuriance of foliage, flowers, and fruit, was consigned to his care. Being appointed to dress it, and keep it, he must evidently have possessed a knowledge of the habits and qualities of plants.

CHAP. V.—PRIMITIVE FORMATIONS.

The very accurate astronomical observations and measurements made by the late Dr. Maskelyne, on the opposite sides of the lofty mountain Schehallion in Perthshire, to ascertain, by the deviation of the plummet from the perpendicular, the relative attraction of the mountain and the earth, and consequently the comparative gravities of the matter composing them, lead to the conclusion, that the mean density of our globe, is greater than that of Schehallion, in the ratio of 9 to 5. Now, as the component rocks of that mountain are considerably denser than the average of those which form the crust of the earth, it appears that the interior substance of the globe must be vastly denser than that of its outermost shell. In the actual figure of the earth, the ellipticity or the compression is about $\frac{1}{312}$, that is the equatorial diameter is to the polar as 312 to 311; but the general contour is very irregular both in density and form, as has been already shown. Playfair justly infers, that the approximation which the figure of the earth has made to the spheroid of equilibrium, cannot, in a consistency with other appearances, be ascribed to its having been once in a fluid state. "The only action of water," (in giving shape to the earth,) "of which we have any distinct evidence in the natural history of the globe, is partial and local, and therefore insufficient to account for the spheroidical figure of the earth."*

From the whole of these observations, we are

* Playfair's Outlines of Natural Philosophy, Vol. II. p. 303.

warranted to conclude, that the earth was originally created in perfect wisdom, of the density and shape best adapted to the equilibrium of rotation, which its terraqueous surface, and relations to organic life required. It could not have spontaneously worked out its actual and only beneficial form, according to any geological hypothesis, that has ever been advanced.

The mean density of the interior parts of the earth, being more than five times greater than the water of the ocean, we cannot recognise the existence of any mighty vaults beneath its surface, into which the waters of the abyss could subside. We are hence forced to conclude, that the dry land appeared, or came forth, by the agency of interior eruptive forces, which, in producing the mountain lands, and marine excavations, gave superficial irregularity to the spheroid. Of the protrusive action of internal fires among the primitive strata, the whole of its surface bears undoubted marks, which it is the object of the present chapter to describe. Farther details are given Book III. Chap. ii.

Chemical science demonstrates that the crust of the earth consists mainly of six substances, silica, or the matter of rock crystal, alumina, or pure clay, iron, lime, magnesia, and potash. Silica, in the crystalline form, is called quartz, and is a large constituent of the primitive mountains, Granite, Gneiss, and Mica-slate.

The Micaceous ingredient of these rocks, is composed of 43 of silica, 22 iron-oxide, 11½ clay, 10 potash, and 9 magnesia. The felspar ingredient of

granite and gneiss, consists of 60 silica, 22 clay, and 14 potash.

The third of the primitive stratiform rocks, is clay-slate, or roofing-slate. It affords by analysis, 49 silica, 23 clay, 11 iron-oxide, and 5 potash.

If to these four bodies, quartz, mica, felspar, and clay-slate, called simple minerals, because they are of homogeneous aspect, we add hornblende and augite, we shall have before us the principal mineral constituents of the primitive shell of the globe.

Hornblende consists essentially of 42 silica, 30 iron-oxide, 12 clay, and 11 lime; and augite of 54 silica, 22 lime, 12 magnesia, and 10 iron-oxide.

Thus we see that silica, clay, lime, magnesia, iron-oxide, and potash, constitute by far the greater portion of the hard materials of the earth, as far as it has been explored.

Quartz, felspar, and mica, blended in distinguishable crystalline grains, constitute GRANITE.

Quartz, felspar, and mica, in crystalline scales or spangles constitute GNEISS.

The Mica-slate formation consists of the mineral of that name; interspersed with masses of quartz.

Clay-slate rock is also the mineral of that name, interspersed occasionally with layers of quartz.

The mountains of Sienite, Porphyry, Hornblende-slate, Greenstone, and Basalt, are composed chiefly of the minerals hornblende, augite, and felspar variously mixed in form and proportion.

Such is a general outline of the substances which form the primitive mountain, and table-land edifices of the terrestrial spheroid. Reduced to their utmost state of simplicity, they become, in the

hands of the analytical chemist, the combustible elements; *silicon, aluminum, calcium, magnesium, potassium, iron;* a mixture of which, at common temperatures, on coming into contact with water or moist air, would cause fire and explosion; and if the quantities were great, earthquakes and volcanic eruptions would ensue of commensurate magnitude.

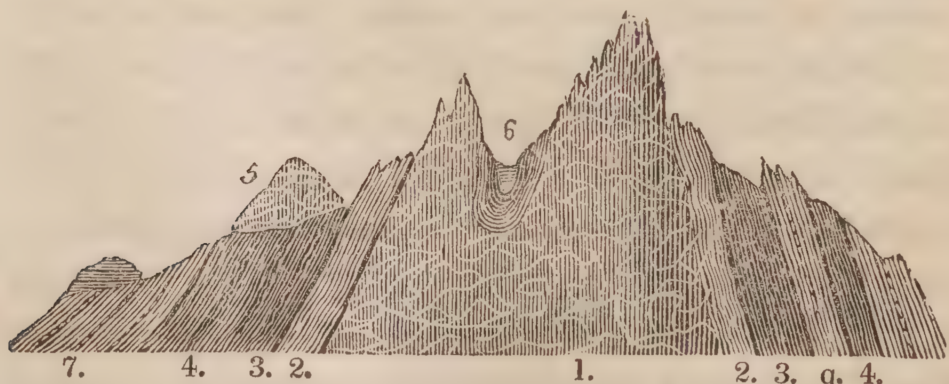
That silica, and its associated bases, which are oxidized at the surface of the earth, and thus deprived of their elementary activity, exist at a moderate depth beneath that surface, devoid of oxygen, in the state of simple combustibles, there is little reason to doubt. The phenomena of earthquakes and volcanoes lead plainly to this conclusion. The heat observed in subterranean regions, progressively increasing as we descend, renders it further probable that these combustible elements exist there in a fluid state; an effect which would result from a very moderate heat, one greatly inferior to what is requisite for the fusion of their oxides.

The primitive envelope of the globe, seems to have originally consisted of concentric strata of gneiss, mica-slate, and clay-slate, with partial layers of semi-crystalline limestone; for such, with a few inconsiderable exceptions, constitute its rocky crust, and are spread over all its regions. These coats, however, no longer lie in layers concentric with the spheroid, but are thrown up into nearly vertical planes, and transpierced in many points by towering masses of granite and porphyry.

On the primordial spheroid covered with its illimitable ocean, these stratiform coats lay in hori-

zontal planes; but with the gathering together of the waters, on the emergence of the land, they were heaved up abruptly into the nearly vertical tables, in which they now universally stand. This remarkable position corresponds to the eruptive violence that caused it. From the shoulders and flanks of the stupendous granite peaks, mantles of gneiss and mica-slate depend in magnificent drapery. These schistose coverings are arranged near the summit in folds almost upright, which lower down, become sloped off with clay-slate and limestone, into a gentle declivity. The coats of gneiss are often contorted into the most singular flexures of rock scenery, demonstrating a certain pliancy of texture at the instant of erection; resulting either from the moisture out of which it rose, or the softening influence of subterranean fire.

The wood-engraving at the bottom of this page, taken from D'Aubuisson, represents the usual structure of the primitive mountains. It is impossible for an unbiassed mind to contemplate this sketch, given by a Wernerian geologist, without seeing its entire conformity with the eruptive mode of formation.



The middle mass (1) is granite, bearing up between its central peaks, a portion (6) of the schistose

strata, which are sloped in opposite directions. 2, 2, are the flanking planes of gneiss; 3, 3, mica-slate. q, a great bed of quartz, subordinate to the mica-slate, which being more refractory, before the weather, has been less worn away than the including micaceous beds, and surmounts them. 4, 4, are clay-slate beds under a more gentle slope. 5, an overlying protruded mass of porphyry. Above 7, a portion of a secondary mineral stratum is seen lying, almost horizontally, over the upright edges of the clay-slate, demonstrating their independent and subsequent formation.

Granite, gneiss, mica-slate, clay-slate, and probably all primitive as well as the largest of secondary formations, are of general extent; a conclusion established by the identity of nature, structure, and mineral locality of the different portions of each of them observed in the different regions of the earth. Thus, for example, in all the countries of Europe, Asia, Africa, and America, into which geologists have travelled, they find a similar granite every where in amorphous (shapeless) masses, composed of grains of quartz, mica, and felspar, almost in the same proportion, and of the same aspect. A similar mica-slate is every where found, consisting of mica and quartz, possessing in all regions the same structure, often imbedding garnets, and having a like mineral position. Now, as nothing indicates these several granites and mica-schists of opposite hemispheres, to be the offspring of local or partial causes, it is natural to regard them as the results of one mighty cause, the members of a systematic whole, the design and execution of one architect.

Observations made in the Alps, in the environs of Genoa, in the Fichtelberg, in the Cordillera of Venezuela, &c. induced M. Humboldt to regard the planes of the stratification of the earth, as forming an angle of about 52° with its meridian sections. On comparing all the observations of this kind made in France, Switzerland, and Germany, we recognise a pretty general direction from west-south-west to east-north-east. These considerations indicate a general cause of the direction of the strata, connected with their original elevation.

The mean inclination of the schistose strata in the Alps, is from 50° to 70°. Humboldt states that mountain acclivities may be reckoned considerable when their angle is 7° or 8°, which is the maximum for carriages; that they are steep at 15°, which is the maximum for loaded beasts of burden; that an inclination of 35° is too great for a man to climb without cutting steps in the rocks; and that even when aided by steps, an inclination of more than 44° is very difficult to scale. From the above sloping measures of mountains, we may judge under what an overpowering inclination (60° or 70°,) the stratiform façades of gneiss and mica-slate must strike the eye of an observer. See Figure, p. 92.

Should doubts be still entertained whether an interior eruptive force, exercised on a general scale, be adequate to raise horizontal strata, into the nearly vertical angle observed in the Alps, the Highlands of Scotland, and other primitive ranges, the following remarks of an accurate observer may remove them. "The formations of Calabria," says Brogniart, "have been for 38 years, the theatre of fearful

perturbations. Horizontal beds have been raised to a perpendicular position; entire masses of deposits have been transported to a great distance, and have been placed in unconformable stratification upon other deposits, and yet no geologist could regard these masses, and these deposits, as belonging to different geognostic epochs."—*Edin. Phil. Journ.* vol. viii. p. 229.

Some facts of sublimer interest have been lately presented by M. Von Buch in his admirable geological sketches of the Tyrolese Alps. "With his characteristic intrepidity and patience," says M. Humboldt the occasional companion of his travels, "he clambered more than 1400 feet high, along the edge of a nearly vertical escarpment, to trace the junction line of limestone reposing on an upheaved wall of granite. The phenomenon is truly of the eruptive class. The granite has pushed itself through the superjacent rocks; there is first *apposition*, and then superposition of the limestone on the granite. It would be difficult to doubt of the granite having acted on the calcareous strata, and of having rendered it granular, as the true volcanic rocks are known to do."—*Annales de Chim. et Phys.* tom. xxiii. p. 263.

"It is not," says Von Buch, "an insulated rock of augite porphyry, it is the entire surface of a province which has here been visibly upheaved to the day (*c'est la surface entière d'une province qui se fait jour*). I doubt not that the noble cupola, formed by the mountains of porphyry between *Meran* and *Clausen*, owes its elevation to the augite rocks, which have pierced entirely through the valley of

Fassa, where they met with less resistance. The great chasms of Sarenthal and Eysack, between Collman and Botzen, change the natural suite of these elevations, into vaulted domes from a mass originally horizontal. A vault, stretched over a great space, would obviously break and form fissures of a bold and deep character, such as we observe in all the valleys of the Tyrol, above Botzen.

"Many years ago I was led to conclude that the whole chain of the Alps, at least all the calcareous districts, owed their elevation to the augite-rock formation; and I am satisfied that none will deny this conclusion, who study with care the southern portion of the Tyrol. This augite formation has broken all the beds which opposed its emergence; forming a kind of enormous vein, whose direction is that of the mountain ridge. It first lifts up or transpierces the red porphyries, then the sandstones, next the calcareous beds, which are transformed, twisted, and set upright, in the most diversified and singular manner. These eruptive forces have operated through the greater portion of the limestone Alps of Switzerland; but they may be most distinctly seen in studying the constitution of the mountains of Mendola, opposite to Botzen. Here a model is presented of the whole calcareous chain of the Alps. The Tyrol may indeed be regarded as a key to the theory of the Alpine formations."

How has it happened, says M. Von Buch, that magnesia could penetrate, traverse, and change the nature of calcareous rocks, several thousand feet high, to form along with them a rock uniform throughout its total mass? The calcareous rocks

themselves contain no magnesia, as the analysis by Gmelin of the limestone of Vigo, in the valley of *Fassa*, proves. It must therefore come from some other source, and it is natural enough to believe that the erupting augite furnishes the magnesia, which is one of its constituent parts.

I conceive that I have discovered, in the environs of Trent, the march of nature in this operation; a march, which appeared so evident at the moment of observation, that I felt the liveliest satisfaction, which ever inspired me during my long wanderings among the Alps. When we arrived at Trent, opposite to the great recess in which the valley of Sugana takes its rise, we were struck with the extraordinary form of two insulated mountains, which stand up behind one another.

The first in a round and pointed cone, resembles a volcano. It bears on its summit a small chapel, whence it derives the name of *Dosso di Santa Agatha*. The second loftier, but equally needle-formed, is called the mountain of *La Celva*. At their foot is placed on one side the village of *Pante*, and on the other that of *Oltre Castello*. On approaching the cone of *Santa Agatha*, we perceive that a portion of the slope towards the town forms merely a mass of rubbish of a dazzling white. Here, workmen are busy sifting the mass of which the mountain is composed, and separating from it sands of different sizes; an operation which appears singular enough on the declivity of a calcareous mountain of nearly vertical strata. If we wish to get a sound specimen of this limestone, we can never succeed; for the pieces instantly fall asunder in the

lines of the fissures that traverse it in every possible direction. Large lumps, though broken into small morsels, the size of a nut, do not show the least appearance of a fresh fracture. It is astonishing, to trace the degree in which this mountain is cracked and cleft; and still more so, to examine the surface of these fissures. They are every where covered with small rhombohedrons, which sometimes present their faces, at others, their edges and their angles. These rhomboids are crystallized dolomite (magnesian limestone). The masses of augite rock which are the causes of so extraordinary a change, are not far off. They are seen at the foot of the hill of *Santa Agatha;* they cross the gorge of the *Fersina*, and re-appear on the great road, in the very village of *Cognola.* They constitute black coloured balls with concentric coats, and a solid nucleus of augite greenstone or basalt.

M. Von Buch has given a drawing of *Langkofel*, a mountain of Dolomite in the valley of Groden in the Tyrol, of very singular aspect. One can hardly imagine how such an obelisk could protrude itself through the strata, and rise up alone to a vertical height of 4000 feet. It is entirely inaccessible, and even the boldest chamois can hardly find on it a blade of grass to browse. Here we behold a vast pyramid of snow-white semi-crystallized magnesian limestone, standing alone above the dark green base of augite porphyry. Towards the right, the nearly horizontal limestone strata are observable which contributed their calcareous matter towards the formation of the dolomite. From an extensive induction M. Von Buch concludes that the augite

porphyry can transform into dolomites any calcareous bed, which it may chance to traverse under suitable conditions, whether that bed be the limestone crag, or of the oolitic series of Jura.

Below the place called Sotto i Sassi in the valley of Fassa there are some striking eruptive phenomena. Here the raising of a particular rock is not the question; but of the total mass of the mountains, and consequently an extensive territory. In fact, the strata of red sandstone and shell limestone occur in such abrupt positions, and at such different heights, that we try in vain to refer all these separate portions to a general level, or even to a common inclination, from their elevation of more than 7500 feet above *Saint-Pellegrin*, to that of 900 feet above *Cattern* and *Tramin*. But wherever these sandstones, and calcareous beds, present such lofty escarpments, they are crowned with Dolomite, in which case we are at no loss to discover somewhere at hand, the augite rock which has raised them. It thence appears natural to conclude that all these beds have been elevated by the *augitic* porphyry, as well as the dolomite, especially since we can hardly conceive how the porphyry could pierce them without pushing them up. A proof of this penetration is given in the geological profile of the Duron; where that prodigious variety of level and façade are seen which accompanies masses violently erupted. Reflecting on the effects of these upheavings, we shall be less surprised to meet with petrifactions of *anomiæ* in the sandstones and calcareous beds 8000 feet high near Sasso in *Val Fredda*. These petrifactions, prior to the eruptive catastrophe

were placed far below the level of the seas. These elevations belong therefore to periods subsequent to the emergence of the primeval land; and are introduced by me here merely to prove the cause and manner of that emergence.

On reflecting on these striking facts, we must not forget that the calcareous ejections of Vesuvius are also constantly composed of granular dolomite. Their aspect alone shows their nature; and the chemical analyses of Smithson Tennant, and Leopold Gmelin, fully confirm this indication from external character. Entirely analogous phenomena are presented in the environs of Rome, on the borders of the lake of Albano; the *peperino* (an indurated volcanic tuffa) is replete with blocks of dolomite of a dazzling whiteness. The limestones of Vesuvius are cleft and split, like the dolomites of Fassa. These dolomites are not confined to that Alpine valley; but they are to be found every where, and under every form, between Pusterthal and the frontiers of Italy. They surround, like rocky islands, with peaks of prodigious elevation, the upper part of the valley of Gröden and Wolkenstein; and thence stretch far and near, over many a valley of augitic greenstone, or pyroxenic porphyry.—*Annales de Chim. et de Phys.* xxiii. 71.

Having premised these general observations, I shall give a particular description of each of the three great primitive envelopes of the earth.

1. Gneiss.—As this schistose body serves no particular purpose in the arts of life, it attracted little attention till in the progress of modern geology, the importance of its scientific relations appeared.

The name, gneiss, was the technical term by which the miners of Freyberg distinguished the roof of their veins, when it was altered, and of a steatitic or greenish appearance, whatever might be its mineral nature, whether granite, porphyry, mica-slate, or our actual gneiss. The little treatise of Werner, on the classification of rocks, which appeared in 1787, finally fixed the acceptation now attached to the word gneiss. He describes gneiss, as a rock composed of felspar, quartz, and mica, immediately adhering to each other, possessing at once a granitic and a schistose texture. The felspar and the quartz occur in grains aggregated together, which produce the granitic structure. These aggregates are assembled in small plates, betwixt which intervene scales of mica. In this way, the slaty texture is produced. Gneiss differs from granite not only in texture, but also from containing commonly a greater proportion of mica; to the abundance of which mineral, it owes its foliated aspect. Felspar is the predominating principle in gneiss, especially in the deepest seated strata; though it is in less quantity than in granite, relatively to the two other ingredients. It occurs in grains of middle size, or even very small, and of a white or grayish-white colour. The quartz is for the most part in smaller grains. It has a vitreous aspect, and an ash-gray colour. The mica of gneiss is in small spangles, often distinct; but sometimes intimately attached to each other, so as to form continuous leaves of moderate size. Its most usual colour is gray, which passes often through every shade to black. To *its* differences the chief variations in the appearance of gneiss are due;

because this rock splitting always in the line of these leaflets, has its fragments coated with them. Gneiss frequently contains crystals of hornblende.

Garnet is the mineral most commonly included in gneiss, occurring thus in the north of Europe, in Norway, and in Greenland, where the crystals are often as large as a nut, and in prodigious number. Humboldt remarked them in great quantities, both red and green, in the gneiss of America, particularly at the Caracas.

Gneiss is very distinctly stratified, and whenever it reposes on a granitic mass, it wraps itself round it, and follows its sinuosities.

It is the rock which contains, at least in Europe, most metallic substances. There is hardly one which has not been found in it, and in such abundance as to become an object of mining. The metallic ores are sometimes in veins, but more commonly in beds. Gold is found in it in Dauphiny, at the foot of Monte-Rosa, and in the territory of Salzburg. The threads and veins of the mountain of Chalances, near Allemont, that afford silver, cobalt, antimony, &c., are in gneiss. This rock, in the Vosges, includes many metals. In the gneiss of Auvergne, threads of lead, silver, and antimony occur. At Freyberg, as also in Bohemia, rich and celebrated mines of silver, lead, &c., are worked. The famous copper mines of Fahlun in Sweden occur in the same rock. It contains iron ore in profusion; as in the iron mines of Scandinavia, at Dannemora, Utoë, and Arendal.

In America, according to Humboldt, gneiss is much less metalliferous.

Gneiss is the predominating rock of Norway, and of all the north of Europe. It abounds in the Southern Alps, and the Pyrenees; in Greece; in the United States of America; and in the south of that continent, it reigns paramount over the loftiest chains of the Andes of Quito. Humboldt observed it also in the mountains of Parama and Venezuela.

This figure represents flexures in the gneiss beds of Bernera, an island in the Lewis; from Macculloch's Western Islands.

2. Mica Schist is a rock of a slaty texture, composed of mica and quartz. The mica almost always predominates, at least it is the most apparent. It is commonly gray, sometimes bordering upon yellow, more frequently on green, in which case it approaches to talc. Here it is not in spangles, as in granite, or in separate scales as in gneiss. The plates, or imperfect crystals, are almost always so blended or run together, that the whole forms continuous leaf-like pellicles. The quartz has its ordinary gray colour and vitreous aspect; it is in small plates of a nearly lenticular form, and interposed flatly between the leaflets of mica. These lens like pieces are often pretty thick, even half an inch in their centre, or become sometimes nearly

globular. The leaflets of mica are always wrapped round them; and when we break schists of this kind, as they always cleave in the middle, these balls or nodules of quartz, stand out on the fragment, and present, under the film of mica, a resemblance to tumours on the skin of an animal. At other times the grains of quartz are so small, and so enveloped in the micaceous matter, that they cannot be discerned; in which case, the rock seems to consist entirely of mica.

The mica passes frequently into talc, and the mica-schist, into talc-schist. One of the most striking examples of this transition is in Auvergne, near Saint-Sernin, on the road from Mauriac to Aurillac. The mica-schist there graduates, without changing even its colour, into a talcous schist, so unctuous to the touch, that if the rock slope ever so little, it is difficult to stand upright upon it. The foot slides, as if it were rubbed over with soap. On the southern slope of the great Alps, from Monte-Rosa to Mont Blanc, the predominant rock is talcous schist, but it becomes at intervals mica-schist, and exhibits all its geognostic characters, in other respects.

Mica-schist is often studded with garnets. Saussure descending the Simplon to Duomo D'Ossola, walked on a path that was almost paved over with them, standing out from its surface like heads of nails. Humboldt observed them, in the mica-schists of America, but they were not so numerous as in the gneiss. The leaflets of the mica enclose the crystals of garnet, just as they do the nodules of quartz.

As mica-slate differs from gneiss, chiefly in wanting felspar, so it readily passes into that rock by the admission of that mineral.

Mica-schist is very distinctly stratified; not, however, in so marked a manner as gneiss, and its strata are often contorted, and folded back in a great variety of forms, as with gneiss. See fig. p. 103.

Of all the primitive formations, mica-schist is the one which contains most foreign rocks; such as beds of talc, quartz, garnets, limestone, &c. Not only does it alternate with gneiss and clay-slate, but it even passes immediately into these rocks in the same district, and sometimes in the same stratum. This introduction of crystals of felspar, sometimes gives it the aspect of granite.

Mica-clate is peculiarly rich in metals, which exist more frequently in beds than in veins. Gold, silver, copper, tin, cobalt, and iron, are found in it.

Mica-slate is perhaps the most extensive of all the primitive strata, at least, in the Alps, in France, Germany, the Highlands, and Islands of Scotland, &c. In the Pyrenees, the formation of mica-schist presents a long ragged belt, resting immediately on granite, and much less extensive than it. In the north of Europe, mica-slate is almost as abundant as gneiss. It is found in different points of the mountains of the United States; and has been observed near Cumana, by Humboldt.

3. Clay-slate.—This rock is well known from its extensive use in roofing houses. It is simple in its aspect; schistose; in the cross fracture dull, earthy, and fine grained. It is opaque, easily reduced to a gray powder, whatever be its colour in mass, and

melts before the blow-pipe into a blackish scoria. Its most ordinary colours are gray, more or less deep, and bluish-black, or sometimes greenish-gray. Iron is its usual colouring principle; but in the black varieties, there is carbonaceous matter. The greater number of the clay-slates split very readily into thin leaves, sometimes plane, sometimes more or less waved. Their surface is occasionally smooth, now and then deeply striated; and dull, or shining with a pearly or silky lustre.

The upper micaceous schists, those which differ most in position and characters from gneiss, appear composed, almost entirely, of mica. When its scales become more compact, and separate only in thicker leaflets, it passes into clay-slate. M. Cordier observed in the Pyrenees, an insensible passage of the one of these rocks, into the other, a fact noticed by Saussure, Von Buch, and many other mineralogists. In these cases the rock must undergo some modification of its constituents.

This is the most distinctly stratified of rocks; and its *folia*, or tables, are parallel to the fissures of the stratification, but they are sometimes so contorted or folded, and the folds continue in the same direction to such an extent, that a portion of the tables comes to be inclined or even perpendicular to the stratification in a part of the bed. There are, however, cases where the rock presents *folia* oblique to the plane of its beds. A remarkable one occurs in Saxony, four miles north of Freyberg. The mountain consists of very distinct layers, mingled with much limestone, alternating with other beds impregnated with plumbago, which renders the stratifica-

tion very manifest. The first beds split asunder very readily, forming with the surface of superposition an angle of about 60°. Count Bournon has remarked that several schists split up very commonly under angles of 60° and 120°; a result which he thought due to the presence of mica.

The strata of the clay-slate formations are in general highly inclined; a position into which they must have been evidently raised by eruptive force. They contain a great number of foreign beds; as schistose talc, chlorite-schist, lydian stone, quartz, and limestone.

Clay-slate is rich in metals, particularly its modification called gray-wacke. Its distribution on the surface of the globe is very extensive. In Scotland it skirts the Highlands from Loch Lomond by Callender, Comrie, and Dunkeld. In the whole of this extensive district, it rests on, and graduates into mica-slate. On the continent it has been traced through a great extent of country; Saxony, Bohemia, Silesia, Franconia, Bavaria, the Alps of Switzerland, Austria, Hungary, and many other parts of Europe. It is found abundantly in the United States, and in immense quantity in South America. Nearly the whole territory between Potosi and Lima is said to consist of clay-slate.

4. Primitive Limestone is always granular, of a semi-crystalline aspect, translucent on the edges, and in colour white or gray. The limestones formed among granite and gneiss rocks, are usually coarser grained, than those associated with clay slate. They often include masses of mica and quartz. Primitive limestone is not in general a stratified rock,

except when it contains mica, to whose tabulated structure it then conforms. It often contains metallic treasures, as in Saxony, Silesia, and Sweden. It is pretty extensively distributed; existing very pure in Dalmatia, Greece, and the Archipelago. Paros was celebrated for its primitive white marble, in ancient times. Great excavations exist in its mountains, of which the celebrated grotto of Antiparos is an example.

Although we have described the order of the above primitive strata from below upwards, to be granite, gneiss, mica-slate, clay-slate, yet with the exception of granite, that order is often violated. The following are a few of the varieties presented by Dr. Macculloch in his Geological Classification of rocks.

Granite, gneiss, limestone, quartz rock; in Glen Tilt. Granite, limestone, quartz rock, mica-schist, gneiss; in Glen Tilt. Hornblende schist also occurs in any part of this series.

Granite, clay slate with fine gray-wacke, gneiss; in Iona and Banffshire.

Granite, gneiss, primary sandstone—Sutherland. Granite, mica slate, secondary strata.

Clay-slate, gneiss, clay-slate. Islay and Ross-shire.

5. Porphyry. This title comprehends a considerable variety of rocks, all of which present amidst a principal mass, crystals or crystalline grains distinct from it, but which are of contemporaneous formation. The basis or paste differs in its mineral nature, but is homogeneous to the eye, and the crystals which it principally contains are felspar.

There is a considerable affinity between porphyry and granite; and the two rocks mutually pass into each other.

6. SIENITE, is a granite, in which the mica is commonly replaced by hornblende; with sometimes a little mica. It is named from Syene in Upper Egypt, where the ancients quarried it in immense blocks. The contrast of the white felspar and black hornblende gives it a pleasing aspect.

7. GREENSTONE, is similar to sienite, only the hornblende is usually in larger proportion.

From the very considerable inequalities in the primitive strata that cover the globe, we may conclude, that they could not be the result of a deposition from one primordial fluid, as Werner affirmed; but that they were distributed originally in that order and form which the AUTHOR of Nature saw fit; so that like the integuments of animal and vegetable bodies, amid a general plan, there is that variety and choice which indicate the volition of intelligence. In our subsequent inquiries into the progressive changes developed on the crust of the globe, we shall perceive the same system of special design and adaptation.

We shall next proceed to advance evidence, in proof of granite, porphyry, sienite, and greenstone, the non-stratified and overlying rocks, being results of projective eruption; whence it may be inferred, that the mighty mountain erections of the earth, all intimately connected with these rocks, have been upheaved by internal force, when GOD bade the dry land appear, and hollowed out the ocean channels. And on this subject, I have the satisfaction to refer

to a faithful and sagacious practical geologist. I allude to Dr. Macculloch, whose researches among the primitive mountain façades of Scotland have enabled him to present a body of geological truths, worthy of entire confidence. The phenomena of Scotland, are not peculiar, but analogous to those observed by continental geologists.

The unstratified rocks are usually of a crystalline structure. They may be divided into two great classes; the one seated beneath, over, or among the primitive schists; the other lying above, or diffused between the medial and superior formations of a later epoch. The former appertain chiefly to the first period of creation, before organic bodies were formed; the latter belong to the whole interval between the creation and the present time.

8. Granite stands at the head of the first group of rocks. It consists of grains of felspar, quartz and mica immediately and intimately aggregated together. The felspar almost always predominates in the mixture; while the mica exists in least quantity. Yet nothing absolute can be pronounced concerning these proportions, as they are subject to great variations. Sometimes the mica diminishes, and eventually disappears in one portion of a granitic mass. The grains which compose this rock ought to be regarded as imperfect crystals, which have mutually interfered with each other, during their formation; the necessary space being wanting for their surface to assume their appropriate geometrical figures. They betray however, at times, their tendency to acquire these forms. Thus felspar occurs in granite as a regular four-sided, or six-sided prism;

quartz as a double six-sided pyramid, and mica in a six-sided plate. In Siberia, mica is found occasionally in granites, in plates large enough to serve for window panes. On the other hand, the grains diminish sometimes in size, so as to be no longer discernible by the eye, constituting a homogeneous looking mass. The colour of the felspar determines the appearance of the rock; whence proceed red, gray, white, and other granites.

Quartz and felspar imperfectly crystallized, and influencing each others forms, produce an appearance of oriental manuscript. Such a stone is called graphic granite. This variety occurs exclusively in veins, particularly in those which traverse gneiss. The felspar is often greatly predominant. Quartz and hornblende combined, as well as felspar and hornblende, are found in granite localities, and therefore belong to the same rock, which distinguishes them from the greenstones of the trap family, or from basalt. These varieties occur in Aberdeenshire, where they are connected with common granite subjacent to gneiss, both by transition and alternation, circumstances decisive of their geological character. When distinct additional crystals of felspar are imbedded in the general mixture, porphyritic granite results, of which rock many remarkable examples are found in Cornwall. Quartz, felspar, and hornblende form a common mixture in some granitic localities of Scotland. To these, mica is occasionally added.

Mica and compact felspar, sometimes containing garnets, constitute white stone. Schorl and quartz

occasionally with felspar, compose the schorl rock of Cornwall, which belongs to the granite formation.

Serpentine may be here mentioned, as forming irregular masses included among the primary strata.

Under granites also we must include those veins which proceeding from them, traverse the adjoining rocks, together with those similar veins, which though of the same mineral composition, cannot be traced in the same manner to a fountain head.

Granite masses often extend over great spaces without any definite form; they resemble immense square beds, separated by fissures or joints, which the inexperienced have sometimes mistaken for strata. At other times the blocks are piled over one another in a huge masonry; with their angles worn by the weather. Such great blocks are sometimes seen standing on edge, with their summits peaked. Nothing of this kind can surpass in magnificence the gigantic spires of granite reared round the slopes of Mont Blanc.

Granite is one of the rocks most abundantly distributed over the surface of the globe, yielding in extent only to mica slate. In the Pyrenees, it forms on the northern slope, nearly from the summit, a band from one to four leagues broad, which constitutes in some measure the *mineral axis* of the chain. To the south-east of France, it composes with the other primitive formations, the greater part of the districts of the Vivarais, Dauphiny, Auvergne, Limosin, and a portion of Bourgogne. To the east, the Vosges are in some measure composed of it. In the Erzgebirge, in Saxony, it seems to

form two principal fields ; one serving as a foundation to the gneiss, mica-slate, and clay-slate ; the other superposed above them. The granite appears to form the body of the *Riesengeburge* chains of mountains in Silesia, and of the Hartz mountains. Along with gneiss and mica-slate, it composes the substance of the Alps. The summits of some of the highest mountains in Scotland, and the central part of the Grampian range, consist of granite. It is rarer in England, occupying a moderate space in Cornwall.

In Asia, according to Pallas, it forms a band in the middle of Caucasus, the Ural mountains, and most of the great elevations of the Russian Empire. It appears also that the Himmalaya mountains, the Imäus of the ancients, which are the highest in the globe, are formed of gneiss, with a few granitic rocks. Granite constitutes the under part of the Table mountain at the Cape of Good Hope. In Mexico, it has been seen only near the coasts of Acapulco. On the great plateau, or lofty table land, it is covered by enormous porphyritic masses, or rather is changed into them. On the high Andes of South America, it is almost always concealed under strata of gneiss, mica-slate, &c. In general, granite does not rise higher than 6 or 7 thousand feet ; but it abounds in mountains of moderate elevation, and in the low districts of Venezuela, Parima, &c. It descends even to the plains nearly on a level with the sea. Of this the banks of the Oronoco, and the coasts of Peru afford examples.

The unstratified rocks of more modern formation, have been called, overlying, by Dr. Maccul-

loch. The several individual compounds of this family are basalt, greenstone, wacke, claystone, clinkstone, syenite, augite rock, hypersthene rock, porphyry, amygdaloids, conglomerates, pitchstone; of which the chief mineral constituents are felspar, hornblende, and augite.

The rocks of this variegated class form tracts of very various extent in different countries: yet they are not so generally diffused as either the primary or secondary stratified rocks. They seem rather to be partial and independent formations, but they are usually connected with elevations of the surface which are often very abrupt. Their masses are generally irregular, having sometimes a slight semblance of stratification. The vertical edges of the successive beds, produce that step-like appearance in the outline of the land, to which the Swedish name *Trap* (stair) has been given. These rocks also occur very frequently in veins; which at some times are traceable to the larger masses, and at others appear insulated. They have been found in contact with every rock, from granite, upwards to some of the most recent of the secondary strata. In granite they occur only in veins; when in mass, they surmount it. But among the stratified rocks, both primitive and secondary, they intrude in veins, as well as in masses, which when partially viewed, appear to be beds. But the parallelism to the other strata is not long maintained, the tabular mass passing up or down into a different stratification.

In the tracts of an uniformly low level, the unstratified rocks rarely exist at all. They are

therefore the concomitants, and, as we shall see, most frequently the causes of elevations of the land. It is usually said that granite forms the highest peaks and ridges of the mountain ranges; to this position there are, however, very many exceptions, where gneiss and mica-slate invest the summits. The unstratified rocks seldom occupy extensive uninterrupted spaces on the surface of the globe; portions of the strata intervene and allow the granite to pass up only in distant points. Thus, in Scotland, we shall find a patch of granite of a few yards diameter, separated by many miles from another appearance of the rock; a fact observable also with traps.

This occasional appearance has, however, a different cause in the two cases. By examining sections of the strata, we shall find the granite merely sinking, and stretching beneath the surface to its next point of emergence, which occurs by the denudation or disruption of the stratiform layers. With trap, on the other hand, there is a real discontinuance of the rock. We are hence led to conclude that the one set of the unstratified rocks is inferior to the strata, and the other is superior, or at least becomes so in appearance. Occasionally, indeed, the former set assumes also an overlying position.

The former class of the unstratified rocks is always so irregular that we cannot predicate their continuity to any distance, near the surface, nor at all with regard to trap.

The relative antiquity of the members in any continuous series of superjacent *strata*, is inferred

from their inferiority; and geology can distinguish certain revolutions, corresponding to relative portions of time, at which they were effected. But with regard to the unstratified rocks, their relative antiquity must be judged of by other criteria. It is by the transmission of veins, from a granitic mass, for example, into an adjoining stratum, that the pre-existence of the stratum is determined, and the posteriority of the granite. This evidence is irresistible. On this principle, a mass of granite is posterior in origin to every stratum in a series which is transpierced by its veins, or dislocated and disturbed by it.

In tracing the relative antiquity of two masses of granite, we must examine whether the veins of one mass penetrate the body of the other. Now this is actually the case; and therefore it is clear that granite has been produced at successive periods. Even three periods have been proved by Dr. Macculloch's observations; but here considerable complexity is introduced.

"The fact of even two generations of granite," says he, "is, however important, in that view which considers it as having been the immediate cause or concomitant of the elevation of the strata. It is easy to demonstrate that the strata have actually been elevated at successive periods, in such a manner as to prove, that the inferior series was twice moved; and the theory of granite provides the means of producing both the effects as easily as the one."

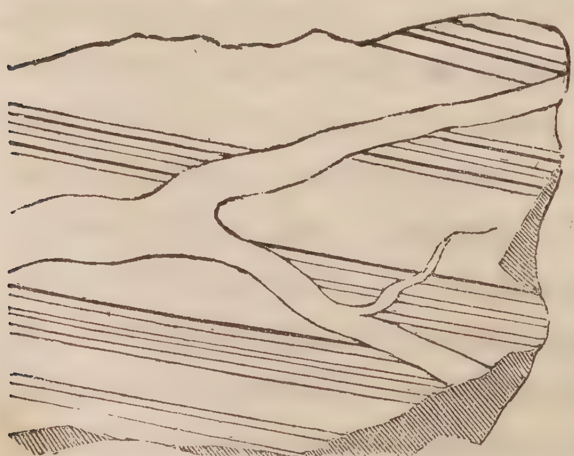
If veins consisting of granite or trap, have not always been traced to masses of these rocks, that has been done, in at least the far greater number of

instances, where the inquiry has been properly conducted. But the parent body may be too deep-seated, and, therefore, invisible. This fact is shown in Dr. Macculloch's account of Sky. He has, moreover, traced the sources of all those veins in Scotland, which were formerly deemed independent. We are, therefore, warranted to conclude, that all such veins are processes from masses of the rocks whose character and constitution they bear. When the veins are very large, indeed they may run to such a distance as to appear independent; trap veins having a much longer course, from its easier fusibility, than those of granite, a far more refractory body. The larger trap veins extend several miles in length; and indefinitely downwards to the origin of the molten mass. But, with granite veins, all the dimensions can often be readily traced. Trap veins rarely ramify; granite veins very often; whence we infer that their generation has differed in some essential circumstance with regard to the condition of the invaded strata. Numerous circumstances in the older strata, as gneiss and mica-slate, prove them to have been at the period of their erection in a flexible state. These are the rocks chiefly invaded by the granite; and such limited and tortuous fissures are, in Dr. Macculloch's estimation, precisely what might be expected from an imperfect rigidity of the strata. The strata invaded by the trap, however, rarely contain indications of flexibility, and would, therefore, yield more readily to the injecting impetus; whence the fissures would be straighter and more extensive.

Most apposite confirmations of this view of the

different effects of fissures on plastic, and rigid strata; on those which yield most easily to a perforating agent, and those which obstruct and turn it aside, are presented in some of the veins of the Western Islands, as in Lunga, and elsewhere. As the veins of trap are most frequently of large dimensions, so they are in general, either vertical, or inclined at high angles to the horizon. Thus they probably indicate by both circumstances, the great depths at which the parent masses lie, and the nature and place of the force which produced the fissures. They occur also often under low angles.

Instead of breaking across the planes of the strata, these granite and trap injections sometimes spread out between them, forming in the case of the quickly consolidating granite, thick masses, and in that of the more fusible trap, coulees, or extensive *laminæ*. A hasty view of such appearances has given rise to the notion of trap and granite being stratified.



Many chemical and mechanical changes occur in the including strata at the place where they are traversed by veins, whether these be of trap or granite. The figure on the margin exhibits gneiss, shifted by a granite vein in the island of Col.

" As it is apparent," says Doctor Macculloch, " that granite has been in a state of fluidity beneath

the strata, and that during this state these have been elevated, in an irregular manner, it is easy to account for the irregularity of its general surface, or for the partial way in which it is found distributed on the earth's superficies. The consequence of the unequal elevation of the strata, was to produce those interior inequalities that have been filled by the yielding mass which was the immediate cause of that fracture, and the concomitant of the force exerted. The production of the veins is another obvious consequence of the fractures or discontinuities formed by the displacement of the strata. It must be remembered, however, that the actual appearance of granite at the surface of the earth is in most cases the consequence of another train of effects, consisting in the waste of those parts of the strata with which it was once covered ; a waste of which the whole globe bears unquestionable evidence. From the progressive state of that waste, it follows that the *apparent* quantity of granite on the earth must be constantly increasing, although itself subject to decay ; and if it really be the basis (or foundation) of all the stratified rocks, it is possible to conceive that the higher parts of the earth might at some future but exceedingly remote period, contain only granite."

We must seek the origin of the trap rocks in the same regions that produced granite. That this is really their source is proved by the masses that lie beneath or among the strata, by the depth and magnitude of their veins, and by the marks of force which accompany their lines of contact with the strata. If any further doubt could exist, it

would be removed by the phenomena of volcanoes. The substances which these produce are not only strictly analagous, in all their essential characters, to some of the trap rocks, but often undistinguishable. The variations that appear, admit of an easy explanation from obvious causes of difference. These rocks having passed through the strata flow over them in certain cases; while in many others there is reason to suppose from the effects following the earthquakes that accompany them, that they have intruded among the strata beneath the surface, so as to have produced those well-known permanent elevations of the land, found in volcanic countries. That they elevate the superficial strata, is also fully proved by the phenomena attending the volcanic Coral islands.—See Book iii. Chap. ii. Sec. i.

It is in the deeper regions of the globe, therefore, that we must seek the origin of trap; where we found that of granite. These substances are essentially of the same nature, but they have been produced at distant intervals. In accounting for the present superficial position of trap we are provided with two resources; that of its flowing out in the manner of lava, so as to cover the strata, and the final removal of these, so as to leave bare that which was once concealed beneath them.

In the district of Morven, a mountainous mass of trap, rising to twelve or fifteen hundred feet, meets a similar mountain of gneiss, in a line not far deviating from the perpendicular: its base being lost beneath the sea. Here the gneiss reposes on, or meets the trap, precisely as it would meet a mass

of granite, and is in the same manner disturbed at the line of junction. This trap mass is indeed connected with a portion that covers secondary strata, and which may be considered as its effused portion. But this part is fast wasting away; and the time may arrive when the trap of Morven shall present all the geological appearances of granite. Had it accidentally possessed the granitic mineral character of some of the syenitic traps of Sky, it would then be supposed an unerupted rock, and a true granite by the Neptunists.

Similar appearances occur in Sky, where masses of trap that seem interminable downwards, pass through the secondary strata, just as granite transpierces the primary. One of these sheets is many miles in diameter; and did neither Sky nor any other district preserve the vestiges of erupted and overflowing trap, it might here also be argued that such matter could not have been ejected from below.

There is in Sky, a mass of trap, indefinite in depth, and of a conoidal form, in a fair, and deep section: It is covered by the secondary strata, which are so bent over it, as to be conformed to its shape. Here is a case exactly analogous to that of an apparently unerupted granite. When in the progress of waste, its summit shall become naked, it will present the semblance of unerupted trap, with the strata conforming to it on every side, just as the primary strata are found to flank mountains of granite.

The volcanic elevations of strata without eruption, present analogies to the protrusions of granite in mountain ridges, carrying up the primitive strata without bursting through them, so as to overflow.

In fact, the thickness and flexibility of these primitive strata afford a sufficient reason for this result. Even the rigid sandstones of Sky have receded before the pressure of the trap; and much more readily would the pliant primary schists, yield before granite.

The admirable crystalline structure of granite, proves it to have lain longer under the influence of heat than the trap rocks. This structure can be produced in our laboratories, by prolonging the semifluid state of fused traps; a condition to which volcanic rocks are liable, from slow cooling in mass. Where granite has been actually erupted, the rocks which it involved may, by long exposure to its action in the ignited state, have been converted into its nature. " An instance occurs in Cantyre, as well as on the continent of Europe," says Dr. Macculloch, " where the gradual conversion of a schistose rock into porphyry, under similar circumstances, is proved in a most unquestionable manner."

That granite has overflowed the strata, like trap, is rendered probable by the fact of granite lying above shell-limestone, in Norway, as observed by Von Buch. No witness can be less liable to suspicion than the person who originally resisted the theory, which his own statements have demonstrated to be true.

"To limit the term granite," says Dr. Macculloch, " to the sole compound of quartz, mica and felspar is merely to abuse a mineralogical term, for the purpose of evading a geological inference. In a geological sense, every rock must be considered a granite, which, whatever its composition may be,

forms a portion of a common mass of that rock in its most acknowledged character."

In Aberdeenshire, the leading varieties of granite accord with the most rigid mineralogical definition; while the superposition of gneiss over a very extensive tract of that rock, can be traced with the greatest facility. But in many places, a variety of this granite occurs, composed of felspar and hornblende, which passes into the ordinary kind, either by the usual fourfold compound of hornblende, quartz, mica, and felspar, or the threefold one of hornblende, quartz, and felspar; to both of which, the term syenite has sometimes been applied. The continuity and gradation of all these compounds, and their inferiority to the primary strata, can be traced without the slightest difficulty. In examining more minutely the binary compound just mentioned, it is observed in many places to assume a fine grain, and thus at length it becomes undistinguishable from the greenstones of the trap family. But the similarity does not cease even here; since in many places it passes in the same uninterrupted manner, into basalt, and at length into soft claystone, with a schistose tendency on exposure, differing in no respect from the trap islands of the west coast of Scotland.

"Similar phenomena have been observed in Shetland. There is nothing wanting, therefore, to prove identity of origin in granite and trap. Nor is it likely that geology will furnish evidence of a more decided nature. This is one of the cases in science, where a few good examples, are as satisfactory as a thousand."

We have perfect evidence of successive formations of trap rocks, from the circumstance of one trap vein being penetrated, and even traversed by another. Many examples of this fact may be found in Dr. Macculloch's Western Islands.

The elevation of Coral islands like Ascension, above the level of the sea, proves that additions of solid matter have been made to the strata beneath them, as there is no other mode of solving this phenomenon; while the actual eruption of volcanoes in the neighbouring parts of the ocean, leaves no doubt with respect to the cause of that elevation.

If in such cases as this, we conceive the surface soil to be removed, as it will be at some future period, we should probably find many places, where the appearances would resemble those produced by granite; that is to say, masses of fused matter, which having been repressed by the solid strata at top, did not burst through and flow over them.

The masses of trap now found in contact with different strata in the series of mineral formations, may have been actually erupted at different periods, and not the consequences of a single deposit on rocks of different natures, which has been separated into distinct parts by the effect of waste. It is not a little remarkable that two deposits of trap, of which the distant succession is proved by appearances that cannot be mistaken, are found in the same place; a phenomenon exactly similar to the renewal of volcanoes at distant intervals, among the ruins of those long since extinct. It must thus be apparent, that whatever differences may exist between trap and granite, whether in their relations

to the strata, or their mineral characters, they are strikingly analogous in almost every essential general circumstance, and that the former may, in a certain sense, be considered as a recent granite; as the granite of the newer strata.*

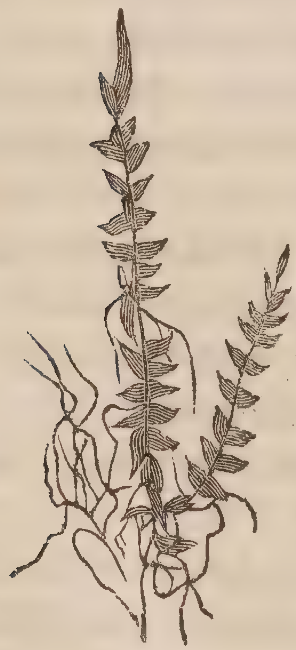
The phenomenon of quartz-veins in granite, gneiss, mica-schist, as also sometimes in secondary rocks; and of calcspar veins in limestone, serpentine, argillaceous-schist, shale, some sandstones, and trap, have afforded subjects of many a frivolous controversy, to the rival partisans of Werner and Hutton. The veins are adduced by the former theorists in proof of the watery origin of the rocks which they pervade; and by the latter, they are regarded as an igneous secretion or separation from the rocks, during their cooling and consolidation. Neither of these conclusions will be received by the geological observer.†

The infiltration of quartz and of carbonate of lime in aqueous solution, through rocks, is proved by the formation of chalcedonies, quartz-crystals, and calcareous spar, in the inflated cavities of trap rocks; and may be traced through every stage of the process.

If any further evidence of the aqueous origin of chalcedonies and agates were wanted, it has been afforded by Dr. Macculloch in an ingenious paper on the vegetable remains preserved in these siliceous minerals, published in the 3d volume of the Transactions of the Geological Society. It is there shown that the mode in which the delicate vege-

* Dr. Macculloch—Journal of Science, xxii. † Ibid.

tables thus become involved, is perfectly simple and consistent with the production of chalcedony. But we must distinguish these real cases, from pseudo-specimens of black arborizations, produced by the oxides of manganese and iron, or by chlorite. Vegetable matter may be easily discovered by mixing a portion of the ground mocha-stone with a little black oxide of copper, exposing the mixture to heat in a glass tube which is sealed at one end, and dips at its other into lime-water contained in a phial. If woody fibre be present, air-bubbles of carbonic acid will come forth, and make the lime-water milky.



The wood-engraving represents apparently a hypnum, occurring in chalcedony.

When real confervæ are present, the vegetable form is so perfectly preserved, that the plant seems to float freely as if in its liquid element. Even the green often retains its lively hue. Some of the larger species of plants enchased in chalcedony have been determined. Daubenton describes the *Lichen rangiferinus*, and *digitatus*, plants possessed of forms which no minerals could imitate.

We are ever too apt to measure the powers of nature by the standard of our own puny means; and when we cannot effect a process in a certain way, pronounce it to be impossible. Geology has been greatly vitiated by this presumptuous procedure.

Not only has an aqueous liquid been found in the centre of quartz, but a group of moveable crystals of carbonate of lime, is to be seen lying in a fluid in a cavity of crystalline quartz from Quebec, now in the possession of Mr. Allan of Edinburgh.

Sulphate of barytes refuses to dissolve in the Laboratory. But native specimens occur containing an aqueous fluid which, when exposed to the air, concretes, so that each drop of fluid becomes a crystal of sulphate of barytes. *Mr. Nicol, in Brewster's Journal, vol. V. p.* 135. Similar crystals may indeed be formed either by water or fire. Crystals of red copper were observed on an old copper statue found in the Soane, in the year 1766; and in the hollow of the leg of a bronze horse, which had lain in the earth some hundred years. By the lava of 1794, copper coins at Torre del Greco, and brass candlesticks, have been converted into crystals of red copper; and in other cases the zinc and copper have separately formed translucent blende, and octohedrons of red copper.

We have now adduced ample, many may think superfluous, evidence to prove that granite, with its primitive crystalline *congenera*, porphyry and syenite, is an erupted rock; the Atlas which has raised on its shoulders the gigantic ridges of gneiss and mica-schist, that constitute the mountain elevations of the globe. Thus, by the expansive power of the internal agents already described, the crust of the earth acquired those irregularities of eminence and depression, that modified the geometrical spheroid around which the waters flowed, and gave it

that distinction of dry land and sea, which fitted its surface to become the dwelling-place of organized beings. There seems nothing hypothetical in these propositions. The circumfluence of the shoreless abyss, proves the spheroidal form of the primordial ball which it concealed; the actual figure of the globe exhibits the manner of deviation from that form which took place when the land and seas were divided; and the position and nature of the mineral masses, show how that deviation and division were accomplished.

BOOK II.—THE ANTEDILUVIAN PERIOD.

SECONDARY FORMATIONS.

CHAP. I.—GENERAL VIEW OF SECONDARY ROCKS.

In Book First we have seen the dry land upheaved out of the circumfluent waters, clothed with vegetation, and stocked with animal life. The primordial mineral strata which we afterwards considered, are void of organic forms. Those which we now proceed to examine, present distinct remains, more or less abundant, of living beings. Here, therefore, we should pause in solemn meditation, on the most marvellous phenomenon, which Nature, full of wonders, can possibly exhibit to the eye of man; the dawn of organization; the mystical transition from the blank of eternity to the fulness of time, from the inertia of the first matter, to the self-movement of life; the first-born of earthly creatures; records of the Creative Spirit, traced in imperishable characters, which every peasant may read, and no sophist can falsify. Here the rudiments of vitality lie embalmed in enduring mausoleums. An ancient catastrophe has rendered these primeval vaults accessible, enabling us to behold the eldest progeny of nature, which display even in their exuviæ, the perfect workmanship of the Deity. The infinite void that separates death from life, yawns before us, the inscrutable pathway between nonentity and existence, which an Almighty Being alone could

traverse. Thus, even these elemental organic forms, are infallible documents of that Eternal Wisdom, which willed a world into being.

The erection of the subaqueous strata, into the primitive mountains and plains, was evidently accompanied with universal disruption. Innumerable fragments of both the upborne and upbearing rocks, were tossed about, and washed down into the congregated waters, along the precipitous shores, and over the bed of the primeval ocean. These shattered fragments becoming agglutinated by their own pulverulent cement, soon recomposed continuous strata, which bear internal evidence of the violence that gave them birth. Thus were formed the *transition* rocks of Geologists, mineral masses which denote the passage between the upright primitive, and the horizontal secondary strata, between those of inorganic and organic evidence. These rocks are called conglomerate, or fragmentary, from their aspect and composition. In the course of the consolidation and re-union of their parts, a few of the organic forms with which the sea was beginning to teem, falling into their crevices, became imbedded in their substance. Hence we see how some vestiges of animal existence, appear in the oldest conglomerate, or greywacke formation. The convulsions, which after a long interval, caused the deluge, have also dislocated many of these conglomerates, so that strata of rounded pebbles assuredly aggregated in a horizontal position, are now found standing in upright walls. Thus the famous puddingstones of Valorsine, in Savoy, are a kind of greywacke schist, containing rounded fragments of

gneiss, and mica-slate, 6 or 7 inches in diameter. That stones of the size of a man's head, previously rounded by attrition, should build themselves up in a perpendicular wall, and stand steadily thus, till fine particles of hydraulic cement, should have time to envelop and fix them in their upright posture, is an absurd and impossible supposition. It is therefore demonstrable that these puddingstone strata were formed in horizontal, or slightly inclined beds, and erected after their accretion. Such effects would be produced on the convulsive emergence of the pebbly banks out of the primeval ocean, either at the deluge, or some preceding catastrophe. There are mountains 10,000 feet high in the Alps, formed of firmly conglomerated pebbles.

It will be proper to introduce here, a general view of the order in which the mineral strata were progressively built up during the antediluvian period under that ocean; "whose bed laid dry by the last great revolution, now forms all the countries at present inhabited."*

TABULAR VIEW OF MINERAL STRATA.

The granites, porphyries, sienites, hornblende, and hypersthene rocks, with greenstones, and basalts, being unstratified erupted rocks, occur in many different and irregular positions among the successive strata.

CLASS I.—PRIMITIVE OR INFERIOR ROCKS.	*Concomitants.*
Order I.—*Gneiss.*	Granites. Hornblende rocks. Limestones. Quartz rock.

* Cuvier.—Ossemens Fossiles.—Discours Preliminaire, p. 135.

Order II.—*Mica-slate.*	As above.
	Gypsum.
Order III.—*Clay-slate.*	Mica-slate.
	Talc-slate.
	Chlorite-slate.
	Gneiss.
	Whet-slate.
	Alum-slate.
	Dolomite.
	Gypsum.
CLASS II.—TRANSITION OR SUBMEDIAL ROCKS.	
Order I.—*Greywacke.*	Conglomerate.
	Clay-slate.
	Flinty-slate.
	Alum-slate.
	Limestone.
	Dolomite, with Encrinites.
CLASS III.—MEDIAL OR CARBONIFEROUS ROCKS.	
Order I.—*Old red sandstone.*	
II.—*Carboniferous or Mountain limestone.*	
III.—*Millstone grit or shale.*	
IV.—*Coal measures or strata.*	Coal-sandstone.
	Slaty-clay.
	Bituminous shale.
	Carbonate of iron.
	Coal.
	Calcareous marl.
	Compact, or Alpine limestone.
CLASS IV.—SUPERMEDIAL OR SECONDARY ROCKS.	
Order I.—*New red sandstone.*	
Order II.—*Magnesian limestone.*	Bituminous marl-slate.
	Copper slate with fishes.
	Breccia—like gypsum.

Order III.—*Red Marl.*	Gypsum and salt beds.
	Variegated sandstone.
Order IV.—*Second Floetz limestone or shell limestone.*	In Germany called Muschelkalk—said to be wanting in England.
Order V.—*Third Floetz or Jura limestone.*	Argillaceous beds.
	Lias of England.
	Oolites, or
	Calcareous freestones.
	Marls.
Order VI.—*Iron sand and greensand.*	Chloritic chalk.
Order VII.—*Chalk.*	Chalk marl.
	Earthy chalk.
	Chalk with flints.
CLASS V.—SUPERIOR OR TERTIARY ROCKS.	
Order I.—*London, Paris, and Isle of Wight basins.*	Plastic clay.
	Clay-marl.
	Sand, lignite, fresh and salt water shells.
Order II.—*First Tertiary Limestone.*	Blue London clay.
	Chloritic coarse limestone.
Order III.—*First local brackish-water deposit.*	Marls, gypsum.
Order IV.—*Second Tertiary Limestone.*	Marls, sand.
	Buhr stone.
Order V.—*Last fresh water deposit.*	Marls, Limestones of Paris and Isle of Wight.

In all these strata, there is usually a repetition of beds of similar composition; that is, of the siliceous, argillaceous, and calcareous, with a texture becoming progressively less compact and crystalline, as they ascend in the scale of superposition. Such

repetitions have been called formation suites. Thus we may have 50 beds of coal, alternating with an equal number of sandstone and shale, and 50 beds of chalk alternating with as many of flint, constituting the coal and chalk formations. When viewed in this aspect, the almost infinite variety of the strata becomes systematised and simplified into a manageable compass.

The preceding table has been compiled partly from M. Boue's table of rocks, and partly from that of Messrs. Conybeare and Phillips. The following is by the Rev. Dr. Buckland.

GEOLOGICAL EQUIVALENTS.

A COMPARATIVE TABLE OF THE ENGLISH AND CONTINENTAL FORMATIONS.

Formations of England.	*Formations of the Continent.*
1. *Greywacke,*	1. Greywacke.
Passing into fine greywacke-slate at one extremity, and	Same, as in England.
into conglomerate at the other.	Abundant on the Continent.
Mountains of North Wales.	Tarentaise in Savoy,
Slate quarries of Penryn.	Matt in Glaris.
Slate of Tintagel in Cornwall, and top of Snowden in Wales, containing marine shells (Terebratulites?)	Slate of Plattenburg in Glaris, containing fish and tortoises.
Slate of Llandrindod near Builth, containing trilobites.	Slate of Angers in France, containing trilobites.
Conglomerate of Killarney and St. David's.	Conglomerate of Valorsine.
2. *Transition Limestone.*	2. *Transition limestone occurs sub ordinately in greywacke.*
Beds of limestone occurring subordinately in the upper region of the greywacke formation;	Thin beds of it at Coblentz on the Rhine.
Dudley, Wenlock edge, Ludlow, Longhope, Llandilo.	In Bohemia, near Prague, Tarentaise in Savoy, Banks of Rhine

Formations of England.	*Formations of the Continent.*
	below Coire in Switzerland, South of Werfen in Salzburg.

II. SECONDARY FORMATIONS, INCLUDING COAL MEASURES.

1. *Old red sandstone.*	1. *Variety of greywacke of Werner.*
In its upper members composed of loose beds of red sandstone, red marle and conglomerate. In its lower regions passing insensibly into compact greywacke; abundant along the frontier of England and Wales.	Seldom appearing on the continent, occurs at Huy on the Meuse below Namur, where it lies under the mountain limestone. The Valorsine puddingstone is nearly of this age, but a little older.
2. *Mountain or Carboniferous limestone.*	2. *Transition limestone of Werner and of Omalins D'Halloy.*
Derbyshire, Alston Moor, Mendip, South Wales; subordinate to the great coal formation, usually found in its lowest regions.	Banks of the Meuse from Namur to Liege; is of rare occurrence on the continent.
3. *English Coal Measures;* Newcastle, Derbyshire, Staffordshire and South Wales.	3. *Independent coal formation of Werner.* None in the Alps, or basin of the Po. Postchapel near Dresden, Friedland in Silesia, and near Ternovitz in Silesia. Namur, Saare Brooke, Saint Etienne in France.
4. *New red Conglomerate.*	4. *Old red sandstone of Werner; Rothe todte liegende.*
Exeter encircling the base of Quantock and Mendip hills.	Base of Thuringerwald.; Schwanden, in Glaris. Lugano, in Italy.

Formations of England.	*Formations of the Continent.*
5. *Magnesian limestone.*	5. Older Alpine limestone; or first flœtz limestone of Werner, divisible into:
	Zechstein (Calcairea Gryphites), containing *Gryphites aculeatus.*
	Asche.
	Rauchwacke. Holen kalke.
	Rogenstein. Stinkstein.
	Kupperschiefer, or bituminous marle slate, with fish.
	These subdivisions are well known in the Thuringerwald; and are occasionally interspersed with salt and gypsum.
6. *New red sandstone and Red Marl.*	6. *Bunter Sandstein, and Roth Thon of Werner.*
Great formation of salt and gypsum.	First and second salt and gypsum formation of Werner. Greywacke of Brocchi in his Val di Fassa; of Ployer in his map of Tyrol; and of Von Buch and Charpentier in their accounts of the salt formations of the Alps.
7. *Oolite Formation.*	7. *Jura Limestone, (properly so called.)*
	Younger Alpine Limestone of Savoy, Switzerland, and Tyrol.
Coral rag loose and rubbly.	Muschel-Kalk of Werner.
	Coral rag, some organic remains in a compact matrix, and used for marble at Roche, near Vevey.
Compact beds of cornbrash.	Compact limestone of Schaffhausen, lying above the Jura Oolite.

Formations of England.	*Formations of the Continent.*
Buckingham marble. Yeovil marble.	Saltzburg marble. Conte marble of France.
Bath and Cottswold oolite.	Oolite of Jura and valley of the Adige.
Lias.	Pierre à gryphites of France and Jura, full of the gryphea arcuata of Lamarck.
	Muschel-kalk of Werner.
8. *Green sand.*	8. *Craie inferieure of the French.*
	Quader sandstein and Plæner kalk of Werner.
Large proportion of the South-East of England.	Younger Alpine limestone of Savoy, forming the summit of the high ridge from Mount Varens in the Vale of the Arve, to Diableret in the valley of the Rhone.
9. *Chalk.*	9. *Chalk.*
	Craie of the French, encircling and forming the base of the basin of Paris.
	Younger Alpine limestone of the Enganean hills and Vicentine hills in Italy.
	Fort near Lunenburg, close to the town, on the side of Hamburg.
	Castle of Cracow in Poland.

III. TERTIARY FORMATIONS.

It is not implied that the following five subdivisional parts of the tertiary formations maintain the same relative order of succession in England and on the Continent; most of them probably alternate, but they are all more recent than the chalk of England, France, and Italy.

English Formations.	*Formations of the Continent.*
1. *London and Hampshire Basins, Lignites, and Glance coal. Imperfect wood coal.*	1. *Basin of Paris; Valleys of the Po, Switzerland, the Danube. Lignites, and Glance coal. Perfect, and used for fires.*
Alum Bay, Isle of Wight.	Monte Bolca, and Arzignan in the Vicentino, Fussen in Bavaria.
Corfe clay pits. Isle of Purbeck.	Titmoning, Teisendorf, Miesbach, and all the coal pits in the valley of the Danube, above Vienna.
	Marburg in Styria.
	Leoben in Styria.
2. *Puddingstone of Hertfordshire.*	2. *Nagelflue of Switzerland, Como, and Salzburg.*
Druid sandstone blocks of Buckinghamshire, Wilts, and Dorset.	Puddingstone of Rigi near Lucerne, and of Bregentz on Lake Constance.
3. *Plastic clay formation.*	3. *Plastic clay formation.*
Clay, marl, sand, and gravel, with marine shells.	Beds of clay, marl, sand, and gravel, with marine shells.
Basins of London, Hants, and Dorset.	Basin of Paris.
	All the edges of the plain of Lombardy; near Parma, Piacenza, Asti, Turin, Vicenza.
	Valley of the Danube.
	Valley of Geneva and Constance.
4. *London clay.*	4. *Calcaire Grossier of Paris.*
Highgate hill, London.	Verona, Vicentine hills, and Monte Berici, in the valley of the Po.
	Loretto S. E. of Vienna, in basin of Danube.
	Tour de Moliere, E. of Yverdun, in Switzerland.
With plants and marine fish. Isle of Sheppy.	With plants and marine fish. Monte Bolca, near Verona. Solenhofen, near Pappenheim

English Formations.	*Formations of the Continent.*
	(probably). Fish of Mount Lebanon (probably).
5. *Fresh water Limestone.*	5. *Calcaire d' ean douce.*
Headen cliff; Isle of Wight.	Basin of Paris; Frienisberg near Berne; St. Saphorin, near Vevey; Horgen near Zurich; Locle on the Jura; Valley of the Rhine, three miles N.E. of Basle. These are principally composed of marl stone, and contain beds of coal, with fresh water shells intermixed. Œningen, near Schaffhausen, with fresh water fish.
IV. DILUVIUM.	IV. DILUVIUM.
Gravel and rolled blocks, both on hills and in valleys, not produced by any causes now in action.	Same as in England.
Gravel of the valleys of the Thames, Severn, and Humber.	Superficial gravel, covering the regular tertiary strata of the valleys of the Po, the Danube, and Geneva.
Blocks of Cumberland granite in the plain of Shropshire, near Bridgenorth; and of Galway granite at Shalk on the south-west of Carlisle, in Cumberland.	Granite blocks on the Jura above Neufchatel, and on the Saleve mountains, near Geneva.
Alluvium.	*Alluvium.*
Effects of causes now in action. Mud of rivers, deltas, gravel of torrents.	Effects of causes now in action. Same as in England, but on a larger scale.

The mountain limestone and great coal formations of England do not occur in the Alps. The tertiary formations which constitute the *molasse* and *nagelflue* of the Great Valley of Switzerland, have

been mistaken for the new red sandstone beds of England. These mistakes proceed partly from the enlarged bulk, and partly from the want of distinct features, and of tangible character, which accompany all secondary strata as they enter the Alps. But their identity with the English formations has been evinced by actual sections. It has been shown that a constant and regular order of succession prevails in the alpine and transalpine districts, and generally over the Continent; and that this order is the same that exists in our own country. It is remarkable that our oolite and magnesian limestones (under the name of alpine limestones) rise into the most elevated crests and pinnacles, that crown the summits of this gigantic chain. The following are among the greatest heights which they reach :—

Ortler in Tyrol, ...	14.466
Jungfrau in Switzerland, ...	12.872
Dodi Berg in do.	10.059
Tiltis, ...	10.000
Diableretz, ...	8.240
Dent de Morcle, ...	7.600

In the Pyrenees also, the same limestones form the most elevated ridge, and great water shed of that vast chain; rising in Mount Perdu to 10,578 feet, and in the Torre de Marbore to 10,260,

CHAP. II.—SUBMEDIAL STRATA.

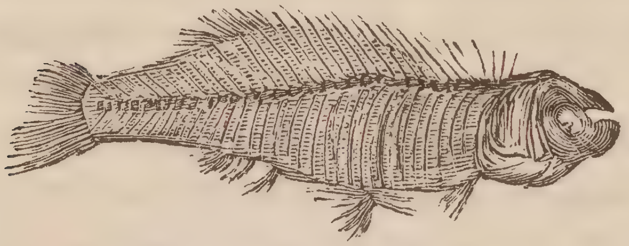
1. Greywacke is commonly composed of grains or fragments of quartz, and lydian stone, among which bits of clay-slate are disseminated. These parts are agglutinated by a cement of an argillaceous

kind, usually impregnated with coarse siliceous matter. The size of the grains of quartz and lydian stone, rarely exceeds a nut; but the pieces of clay-slate are sometimes as large as the hand. Occasionally these fragments are so comminuted, as to be no longer discernible; the rock takes then a schistose texture approaching to clay-slate.

But the main body of the submedial rocks is composed of clay-slate itself, containing certain subordinate beds, such as masses of talc, &c. The clay slates of Glaris, in Switzerland, celebrated for their casts of fishes, are accompanied with talcose rocks. Here also, we find alum-slate, which is merely an argillaceous schist, impregnated with carbon and sulphur; the latter probably in the state of sulphuret of iron. The transition clay-slate of Sweden and Norway, is so rich in these beds, as to be worked for them alone. When exposed to the air, they get covered with a snowy efflorescence, just as happens to some of the argillaceous slates of our coal measures. This was finely exemplified in the waste coal workings that form the Hurlet Alum mines, near Glasgow. The carbon occasionally accumulates to such a degree in some portions of the slate, as to form masses of stone coal (anthracite,) a substance which burns with difficulty, and can be made use of merely for calcining limestone. The surrounding slate affords vegetable impressions of reeds and analogous plants. The animal exuviæ are not numerous in these transition strata. They consist of madrepores, trilobites, ammonites, and terebratulites, casts of turbinites and striated *camites.* But certainly the most characteristic feature

of this submedial formation, is the impressions of fish, indicating most clearly the dreadful turmoil which presided at its origin.

Fish which perish by a natural death, necessarily become the food of other fish like themselves, or of crustacea. We need not therefore be surprised, at finding none of their remains, in situations which abound with them in the living state. It is not unusual however, to find a great number of fossil fish in one district, as in Monte



Bolca, and other localities; where a volcanic eruption, or some other sudden revolution had killed them all at once. In certain places their remains occur, lying on their belly, or lengthwise, with their fins and tail extended. These remains, in some cases, consist of bones, spines, and scales, distributed in their natural positions, In others, they are found in a constrained posture, suggesting the idea, that they had perished in boiling water; examples of which, have occurred in the sub-marine volcanoes of modern times. Lastly, in certain localities, as at Plattenberg, in the canton of Glaris, they are in a flattened state, and covered with scales, but destitute of bony skeleton.

It cannot be doubted that the revolution which caused the vast accumulation of remains found at Monte-Bolca, must have been sudden, and that they were speedily covered after death, by the mineral deposit in which they are now buried; for one of

these fossil fish, now in the galleries of the French museum, belonging to the genus *blochius*, had not time before it died, to let go another fish which it was in the act of swallowing. In our climates, when any fish, (and especially one furnished with an air bladder,) dies in summer, it remains at the bottom of the water, for two or three days, it then rises to the surface before it becomes tainted, and falls to the bottom to rise no more, till putrefaction disunites its constituent parts. Hence, if some days had elapsed between the death of the *blochius*, above described, and its getting impacted in the strata, it would have mounted to the surface, and thus have been separated from the fish, which it was swallowing, when arrested by the fatal catastrophe.

Had we no such instance to prove the rapidity of the convulsion of nature, we might adduce cases of fish found in the same locality in which we find the bodies of others, that had been newly swallowed. These show how quickly they had been killed, after satisfying their appetites, before the digestive powers, so vigorous in these animals, had time to dissolve their food. We ought not therefore to be surprised in the least, at meeting with so few fossil fish, among the shelly strata, quietly deposited at the bottom of the sea. Those which we do find, have been buried immediately after death, in a bottom of sand, or mud, which concealed them, and hindered them from mounting to the surface.

Remains of fossil fishes are found, not only in the transition rocks, but also in more recent formations, as in the strata, anterior to the chalk, in this substance, and in still more modern formations.

These remains are sometimes converted into a calcareous, siliceous, or pyritous substance; but most frequently they have not changed their nature.

We shall enumerate the principal localities in which fossil fishes, or ichthyolites, have been found.

1. *Glaris.* The substance containing the fossil fish is a blackish slaty rock, sectile, containing distinct spangles of mica, as also limestone in small beds parallel to the stratification. Haller says that in the slates of Glaris he found very fine impressions of the ferns of the Antilles. The fish are recognised by the marks of scales, fins, and the general external outline. They are not accompanied with shells. The slaty rock has been referred to the transition class of Werner.

2. *Mount Pilate,* situated in the canton of Lucerne, almost in the centre of Switzerland. On the summit called Tomlishorn, fully 7000 feet above the level of the sea, the ichthyolites occur in schists which are easily separated in plates. In almost every tablet a fish is found. The bone is reduced to powder, but it has left its impression. A great quantity of teeth have been observed. The rock is calcareous mixed with quartz and clay. Nummulites, Madrepores, and other broken shells abound, in the limestone. At the foot of the *Esel,* two petrified trees occur, at a height where trees can no longer grow.

3. *Eisleben.* It is in the county of Mansfeld, Thuringia, Voightland, and the Palatinate, that the most remarkable localities of a species of ichthyolites occur, contained in metalliferous slates. The flesh of the fish seems to have penetrated and

altered the stone, that now occupies their place. Sometimes, the trace of the fish takes up hardly any room, being represented by scales, fins, and flattened heads. The stony layers in which the fish have been compressed, may be split into two plates, on each of which, an image is exhibited. These fish, are in every possible attitude, some of them three feet long, mostly lying on their backs, or recurved into constrained positions, with their heads usually crushed and disfigured. The substance enclosing them is a cupreous marly schist, impregnated with bitumen, and sprinkled with argentiferous pyrites, or sometimes with mercury in the state of cinnabar. These schists must be of very early formation, since there are found above them, beds containing belemnites, entrochites, and ammonites. Fossil fish similarly situated occur in France, near Autun, in a mountain called *la Muse.*

4. Fossil fish are also found in superjacent formations; as at Grammont, near Beaune, in mountain limestone; in the high mountain of Pietra-roya, a portion of Mount Mates in Italy; at Stabia in the same kingdom; in the chalk beds, of the Paris basin, of the mountain of Saint Pierre at Maëstricht, and of Perigueux and Gravesend; in the coarse shell limestone quarries of Nanterre, of St. Denys, and other places, the most remarkable of which are at Solenhoffen and Pappenheim in the valley of Altmuhl. The fish are accompanied with crustacea, and a species of lunulæ and asteriæ.

5. *Monte Bolca,* in the Veronese. The most celebrated of the ichthyolite localities is undoubtedly that of Monte Bolca, or Vestena-nuova. This

mountain is volcanic, and elevated a thousand feet above the limestone quarry. That containing the fish is pretty low, and reclines against lofty mountains of shell limestone. The mountain of Vestenanuova is composed of two kinds of rocks; one is merely a very hard marl, forming thick beds, apparently devoid of organised remains; the second is a fetid marly slate, which may be cleaved into thin leaves. The fish are found only in one bed two feet thick. They consist of skeletons, sometimes in perfect preservation, placed, without any token of violence, on their belly or side. The bones occur in a somewhat friable state. Occasionally there is nothing but a concave impression within the slate. The scales are seldom to be observed, but merely a trace at times coloured, indicating the form of the fish. The greater part of them seem to have been seized, or rather deposited in the stratum, in a perfectly entire state; but a few are observed to have been somewhat decayed before deposition. The rock owes its origin, most probably, to the adjoining volcano. Shells are very uncommon.

6. *Ichthyolites* have also been found in fissile marly slates in the Vivarais, the Vicentin, Friuli, Antibes, Dalmatia, Cerigo, Mount Libanus, Tripoli, Malta, Sicily, near Cadiz, Barbary, Iceland, and in many other places.

For an account of the genera and species, the reader is referred to a copious detail in the article *Poissons Fossiles* of the *Dictionnaire des Sciences Naturelles.*

In the famous locality of Monte-Bolca, the following genera are found: the shark, ray, file-

fish, sun-fish, globe-fish, palæobalistum, trumpet-fish, pike, silurus, herring, pipe-fish, cod, blenny, goby, mackarel, bull-head, gurnard, gilt-head, sciæna, perch, flounder, amia, fistularia, flying-fish, muræenophis, eel, dory, and several others.

From the genera that have been recognised in all the localities, it appears evident that those of Glaris, Eisleben, Pappenheim, and Vestena-nuova, have been formed by deposits in the sea, or rather by submarine volcanoes. The whole, with the exception of Montmartre, seem to have been the result of volcanic violence; even that of Aix, most probably belonged to the same head, since Saussure states that there formerly existed powerful volcanoes in that district.*

These slaty conglomerate rocks are very rich in metals. Here are found the celebrated mines of the Hartz, which yield annually 60 thousand hundred weight of lead, and a considerable quantity of silver. A great portion of the mines of Hessia, of the territory of Naussau, and the district of Ardennes, are in similar schists. Several of the richest veins of Mexico, and particularly the noblest vein in the world, *la veta madre*, at Guanaxuato is in these intermediate formations; to which also we must refer the famous mines of Potosi.

The greywacke formation is the first of Scotland in geognostic importance. It constitutes alone

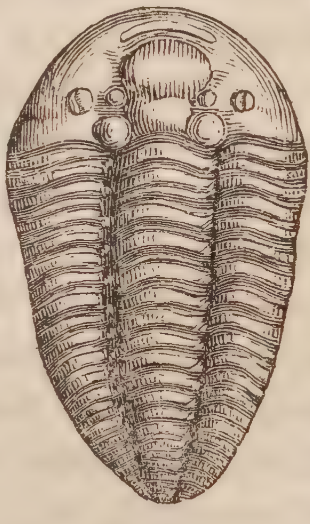
* Casts of fossil fish have been lately found in the old red sandstone of Clashbennie quarry, parish of Errol, Perthshire. The imbrication of the scales is perfectly visible; as is also their silvery and shining appearance. No entire skeleton has yet been observed. The geological locality is equivalent to the greywacke of Plattenberg.

almost all the mountain chains of the south of this country The district of Leadhills is nearly in the central portion, where Lauder rises to 3130 feet. This chain of greywacke crosses the island, extending from sea to sea. It abounds in metallic veins grouped together, especially in its western part. Various ores of lead, zinc, iron, nickel, and copper occur, of which the first alone is an object of commercial importance. It is superfluous to attempt an enumeration of the places where this transition schist is found; as it is an essential constituent of almost every country on the surface of the globe, demonstrating the universality of those interior convulsions which were accessory to its production.

Limestone.—The limestone of the submedial class is to be distinguished from the other limestones, chiefly by its position. Its grain is scarcely so highly crystalline as that of the limestone found among the primitive rocks. More frequently its fracture is scaly, approaching to compact, and even completely so. It is uniformly translucent on the edges, unless when occasionally mixed with too large a quantity of foreign matter. Its colour is very various. Most part of the marbles employed in architecture, are from the intermediate rocks; the primitive being alone adapted for statuary, by the fineness of its grain, and the purity of its white. In the mixed beds of slate and limestone, each of the two substances is formed by itself; the limestone occurring in flattened, ovoid, or lenticular masses, disposed in nearly parallel planes, separated and enveloped by the schistose mass. Among the

minerals contained in the intermediate limestone, we may distinguish hyaline quartz, lydian stone, (flinty slate,) and mica, or talc, passing into steatite. In some of the black coloured beds, of the North of France, the carbonaceous matter is in such quantities, as to form masses of stone coal (anthracite), approaching occasionally in its nature to common coal.

In the older limestones of Flanders, a great quantity of zoophytes have been found. These with madrepores, and millepores, are sometimes so abundant in certain intermediate strata, that M. Schlotheim was led to believe them the work of these animals, like the limestone reefs of the South Sea. The orthoceratites, which approach to that order of animals, also occur in considerable abundance, along with fragments of entrochi and encrinites. The shells most frequently found there, are terebratulites, turbinites, certain ammonites, and belemnites. But the only fossil which appears to be characteristic of the transition limestone, is the trilobite, a singular extinct animal of either the crustaceous or insect tribe.



In a great many points of the Hartz mountains, particularly towards Blankenberg, it furnishes a fine marble like that called by the Italians, *rosso corallino*. In Saxony, it occurs in the vicinity of Kalkgrün and Wildenfels, from which it extends even into the territory of Bayreuth. There it forms different marbles, one of which is black, and approaches

closely to that known in Italy, under the name of Nero d'Egitto. It is full of fragments of entrochi. In the South of France, among the Pyrenees, the transition limestone is very abundant; constituting the principal mass of the intermediate formations of these mountains. In the north, it forms a portion of the great transition zone, which stretches from Flanders into the Hartz. Here it alternates repeatedly with roofing slate. It furnishes Paris with black marbles (of Namur and Dinant). The *granite marble*, of the Ecaussines, 4 leagues north of Mons, has white spots, which are fragments of shells, particularly *encrini*, converted into lime-spar. These transition rocks, serve as a basis to the coal district of Flanders. The Alps are flanked by a prodigious calcareous belt, which extends from France into Hungary, from 8 to 15 leagues in breadth, rising into mountains upwards of 12,000 feet high. A portion in contact with the primitive formations, belongs to the intermediate class, and alternates with clay slate. A few trochites and encrinites occur in it.

In England, one narrow chain of submedial limestone, runs through South Wales, in a south-west direction from near Wolverhampton, south of St. David's; another in North Wales passes from near Ormeshead, south through Llanrwst to Bala; a third goes from Shap towards Ulverstone, through Westmoreland; fourthly, there are several ridges of it near Exeter and Plymouth; besides a few smaller separate patches. It occurs in Scotland, near the Crook on the road to Moffat, and in many other situations.

Gypsum is very common in the intermediate

strata. That of the Alps is usually of a very white colour, a fine grain, and sometimes compact, containing also particles of limestone, mica, or talc, sal gem, and sulphur. The salt mines and springs of Bex, near Geneva, are supposed to belong to a saliferous gypsum lying in beds, among a submedial limestone impregnated with argillaceous and coaly matter. Among these are strata of clay-slate passing into greywacke, containing a pretty large quantity of salt in grains, nodules, and veins, 7 or 8 inches thick. The gypsums of Tyrol, Salzbourg, Wieliczka, &c. lie in a mass of clay; they are anhydrous in the interior of the mines, but at about 60 feet from the surface of the ground, water has been introduced, converting them into ordinary Paris plaster. The gypsum of the environs of Tarascon, in the Pyrenees, rests on the primitive rocks, and is covered by a limestone containing ammonites.

CHAP. III.—MEDIAL OR CARBONIFEROUS STRATA.

We now approach a subject of great geological interest, the coal-measures; the main spring of the manufacturing prosperity of Britain. On entering on these formations, a few remarks on their general features may be useful. We no longer find ourselves among rocks, consisting of such a variety of minerals, and mineral elements, which being differently combined, according to complex laws of affinity, and peculiar local circumstances, produced a great diversity of compounds. Here we shall have more uniformity; we shall observe masses relatively simple, deposited one over another in

the form of layers of considerable extent. The superpositions will be very manifest, the relative ages incontestible, and the systems of beds constituting a whole, or the formation-suites, will be much easier to recognise and determine.

Strata of limestone, alternating with strata resulting from the debris of primitive rocks, make up the entire body of secondary formations.

To the limestone properly so called, gypsum is sometimes joined. The debris of ancient rocks unite here to form breccias, puddingstones, sandstones, sands, clays and marls. These several matters, by the differences which they present in their associations, and in the substances which accompany them, or which they include, enable us to determine their diversities of epoch or deposition.

The numerous vestiges of animals and vegetables, which occur in secondary districts, will afford us a great facility for effecting these determinations ; the different formations possessing always some fossil peculiar to them, which enables them to be distinguished, even when they occur in insulated spots, so that their true geological locality could not otherwise be known. The secondary formations which have been most studied, are those of England, the centre of Germany, and the North of France.

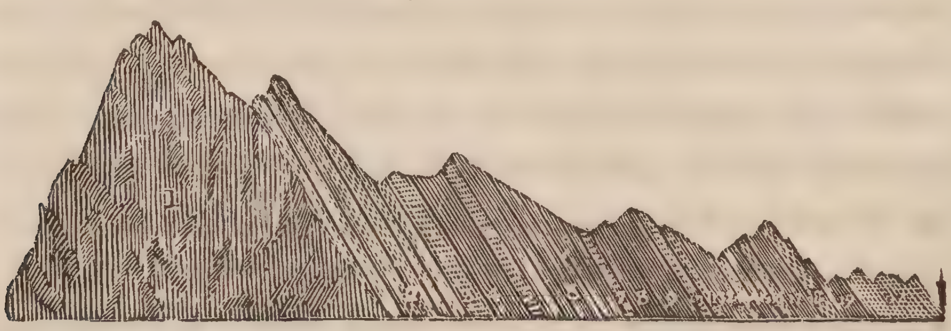
In the central parts of Germany, in Thuringia, Mansfeld, &c. a great many mines of coal, copper, and salt, have made the strata be well understood. They present four great formation-suites. The first which reposes immediately on the primitive or transition beds, is chiefly composed of sandstone, and bears the name of red sandstone, or coal sandstone;

the coal measures forming a part of it. The second which comprehends the most ancient of the secondary limestones, is divided into two principal layers. The third is a newer sandstone called the spotted or speckled sandstone, or sandstone with clay. And the last is a limestone enclosing many shells, and called in consequence the shell limestone (muschelkalk).

Mr. William Smith was the first geologist who showed, in his admirable researches and map, that England is regularly distributed into strata, that the order of superposition is never inverted, and that exactly similar fossils are found in all the portions of the same stratum, and at great distances asunder. The following is the order given by Mr. Smith. On the primitive territory which forms the western portion of England, there exists a red or brown sandstone, which appears to be a greywacke, above which lies the encrinal or mountain limestone, which some have described among the intermediate class. We find after this, progressively as we advance towards the east, a succession of great beds which dip towards that point of the horizon. These beds are:—

1. The coal formation or coal measures;
2. Yellowish magnesian limestone;
3. Marl, and red sandstone, gypsum, rock-salt;
4. Argillo-bituminous limestone (Lias), containing many ammonites.
5. Blue marl with belemnites, gryphites;
6. Oolitic limestone;
7. Compact limestone with schistose clay;
8. White and sandy limestone—a thin layer;
9. Schistose clay of a deep blue colour; calcareous and bituminous;

10. Ferruginous sand, containing calcareous masses, fuller's earth, clay;
11. Limestone with remains of madrepores and pisolites;
12. Bluish marl;
13. Green sand, often chloritic sandstone with calcareous cement;
14. Chalk;
15. Sand;
16. Plastic clay;
17. Bluish or London clay.



Sectional view of the series of strata from Snowdon to London.

1. Old red sandstone; 2. Mountain limestone; 3. Coal measures; 4. Magnesian limestone; 5. Red marl; 6. Lias; 7. Oolite; 8. Limestone; 9. Clay; 10. Sand; 11. Lime marl; 12. Green sand; 13. Chalk; 14. Sand; 15. Clay; 16. London clay. From the narrow bounds of the figure, strata 4, 5, &c. are placed in an inclined, instead of a nearly horizontal position.

An analogous suite of strata has been observed in France, and other parts of the continent; which, if not entirely the same, are at least equivalent formations; that is, parallel and congruous.

Before entering into the details of the several strata, we may take a general view of their relations. The red sandstone passes by an uninterrupted continuity into the greywacke; it is the same substance in every respect, only the bed alternating with the clay-slate is regarded as belonging to the *intermediate* class. The coal-sandstone is linked also with other rocks, which extend even to the primi-

tive formations, of the eruptive kind, namely, granite and porphyry, as at Thuringerwald. The connexion of the intermediate limestone, with the coal measures, is in like manner certain. On quitting the district of Newcastle, which presents the coal formation in its utmost purity, and advancing towards Derbyshire, we observe first of all some beds of encrinitic or mountain limestone, placed between the sandstone strata, which increase in number, and eventually become the predominant rock. It appears, therefore, that in the succession of mineral strata there is such a concatenation, that on departing from one line, it is difficult to point out any broad plane of demarcation, either above or below; and we are led by the most striking relations to consider certain masses as forming but a single suite, which viewed separately, and at a great distance, are perfectly distinct.

The coal measures form most regular beds of stratification, with peculiar inflections worthy of attention. A very large portion of this formation is deposited in valleys, at the foot, and along the flanks of primitive mountains; it is moulded on their bottoms and sides, and partakes of all their inequalities; thence arises the contorted shape of certain strata of coal; thence their direction parallel to that of the sides of the basin which encloses them, and determines their sinuosities; thence their great inclination against the precipitous flanks of a valley, their gentler slope towards the middle, where they become horizontal, and their renewed ascent and inclination on the other side of the valley. Geological observation proves in general that these

strata are now in the same situation, as at the period of their deposition on the primitive rocks; and consequently that neither eruptions nor revolutions have set them up in the inclined posture which they exhibit in very many places. When they are greatly inclined, they become gradually thinner transversely towards the upper edge of the basin, and thicker towards its bottom, an effect analogous to what would happen to materials deposited on the sloping surfaces of planes lying more or less oblique to the horizon. To this statement, there are no doubt many exceptions; for it is well ascertained that several beds have been raised up subsequently to their deposition and consolidation. We may mention the beds of Anzin, near Valenciennes, so singularly folded backwards and forwards. To form an idea of their derangement let us conceive a stratum dipping towards the south at an angle of 75°; that at a certain depth, two hundred yards for example, it turns suddenly back, rising towards the north at an angle of 15° with the horizon; after proceeding in this direction for nearly 600 yards, it is folded back again, so as to dip southwards anew at an angle of 75°. It thus presents nearly the figure N.

Let us now imagine a great number of strata of coal, sandstone, and shale (slate-clay), having all this shape, incased one within another, and thus forming an enormous bale, half a league broad, and several leagues long, and we shall have a pretty exact idea of the system of beds in which lie the valuable coal-mines of Anzin. In these convolutions the strata of coal are frequently broken, their tabular masses are intermixed with those of the rock, but

sometimes also the foldings are rounded off, without any appearance of rupture. A bed nearly two feet thick was observed by M. D'Aubuisson, folded into a very regular curvature, forming an arc of about 100°, with a radius of 4 yards; all the tables of the coal followed this curvature, preserving a perfect parallelism with the contour, and the same thing was manifest in the mineral strata of the roof and the floor.* The collieries of the environs of Mons, and of several other places, present foldings of the same kind.

What may be the cause of such extensive, extraordinary, and we might even say grotesque convolutions? We may remark, in the first place, that the stratum of slaty clay, or sandstone which forms the roof of a bed of coal in one of its portions, serves as a floor a little further on; and that consequently, had the foldings been of original formation, the stratum of sandstone deposited immediately after that of coal, should have been placed there partly above and partly below, an absolutely impossible event, especially when the deposition is mechanical like sandstone. As no change of position in the coal measures taken in their totality could exhibit a case, where the bed of sandstone would have been deposited entirely *above* the stratum of coal, we must necessarily admit that the form of the beds is owing to a mechanical cause which has acted posteriorly to their formation, but before their complete consolidation, since the beds present in several places curvatures perfectly rounded off without any fracture.

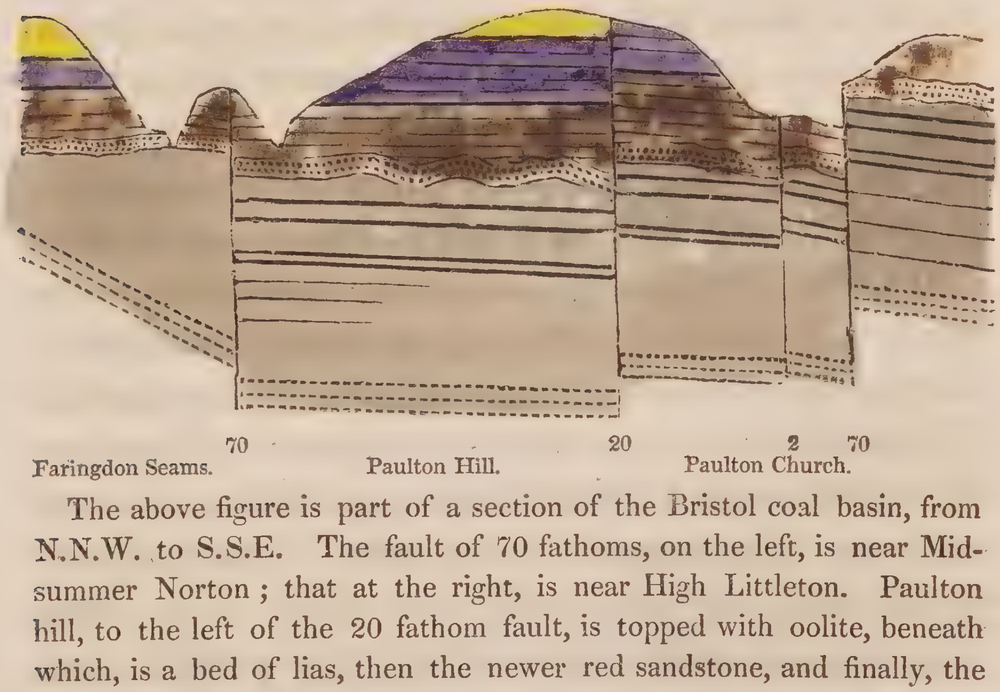
Contortions analogous to the above are displayed

* Traité de Geognosie, Tom. II. p. 285.

in a particularly striking form on the coasts of Bridesbay, Pembrokeshire, near Littlehaven. Generally speaking where solid masses of limestone and sandstone associated with the coal are raised up in high angles, but still placed in nearly regular planes, the more tender argillaceous or slate-clay beds are usually folded, or as it were crumpled together. The Mendip hills and adjacent collieries in Somersetshire afford good illustrations of this fact, which strongly suggests the idea of a mechanical force having elevated the more solid rocks in mass; while the more pliant materials, yielding to its lateral pressure, have become irregularly contorted. These phenomena cannot be ascribed to any intrinsic agency like crystallization; for they appear common to all rocks, even those most decidedly mechanical in their structure. They are equally observable in the most recent members of the oolitic series in the Isle of Purbeck.

The faults, slips, or dislocations of the coal-fields, are irresistible evidences of their having been affected by violent mechanical convulsions, subsequently to their original formation. These fissures which traverse the strata in so many directions, have occasioned the downfall, and upheaving of the two portions which they disjoin. Hence when the miner advancing in the line of his seam, comes to a fissure, he no longer finds the coal on the same level; the corresponding part of it, is one, two, three, or more yards lower or higher according to the force of dislocation. These fissures are frequently filled with fragments of sandstone, and the other substances of the coal formation, when they

are called faults. Their magnitude is often considerable, amounting sometimes to 100 yards in thickness. At other times the seams of coal are not deranged from their position, but the portions contiguous to the faults are as it were contorted or broken. It is obvious how interesting to the miner, the knowledge of these dislocations must be, of which a great many are occasionally crowded into a narrow space. They are sometimes called traps, from their resemblance to a step, so named in the northern tongues. The direction of the fissures is commonly vertical.



70 20 2 70

Faringdon Seams. Paulton Hill. Paulton Church.

The above figure is part of a section of the Bristol coal basin, from N.N.W. to S.S.E. The fault of 70 fathoms, on the left, is near Midsummer Norton; that at the right, is near High Littleton. Paulton hill, to the left of the 20 fathom fault, is topped with oolite, beneath which, is a bed of lias, then the newer red sandstone, and finally, the pennant and coal seams. The wood-engraving is accurately copied from a section accompanying the Rev. Dr. Buckland's and Mr. Conybeare's excellent paper on the south-western coal district of England.—*Geological Transactions, New Series, Vol.* I. *p.* 210.

The coal-measures, especially in Great Britain, are also sometimes cut across by great veins or dykes of a basaltic nature. At Newcastle these are very numerous, and their size is sometimes prodigiously great. They extend through a great many

miles of country, with a thickness of ten, twenty, or even fifty yards. Their colour is blackish-green; they are compact, and sometimes amygdaloidal, having almond-like concretions interspersed in their substance. In their proximity, the coal is carbonised, assuming a grey colour, and a reedy structure, the sulphur is sublimed out of the pyrites, and the sandstone has acquired considerable hardness. These changes extend to several yards distance, even to twenty in some situations. Occasionally these veins seem as if composed of two portions separated by a middle space, a few yards wide, which is filled with the materials of the coal formation, more or less altered. In one of these interstices, galena has been found. The two portions of the same coal-seam remain sometimes on the same plane, on either side of the vein; but at other times, the deviation is very great, being nearly 200 yards alongside of one dyke in Northumberland; that being the most remarkable one of the district.

Basaltic dykes traverse the subjacent formations of limestone and millstone-grit, as well as the coal measures themselves. They may be seen indeed penetrating up into rocks of much later date. Limestone is often rendered highly crystalline and unfit for burning into lime, from the influence of this rock, as happens to the two undermost strata at Wratchiff crag in Northumberland. Slate-clay, or shale, is turned into a substance like flinty slate or porcelain jasper. This is the case with the stratum lying immediately beneath the upper bed of basalt at Wratchiff crag; and the coal is *invariably* charred, into blind coal or coak, when in con-

tact with it. The sandstone on which it sometimes reposes, is changed for some depth to a brick-red colour. The most considerable dyke in the neighbourhood of Newcastle, is that which passes through the Coley-hill, about four miles west of the town. The dyke is vertical, and 24 feet thick. The basalt composing it, lies in detached masses, which are coated with yellow ochre. The removal of these brings to view thin layers of indurated clay, with which the fissure is lined, which breaking into small quadrangular prisms, are used by the country people for whetstones. In this argillaceous substance, clay-ironstone impressed with the figure of ferns is very abundant.

The upper seam of coal occurs here at about 35 feet beneath the surface, and where, in contact with the dyke, is completely charred, forming an ash-gray porous mass, which breaks into small columnar concretions, exactly resembling the coak obtained by baking coal in close iron cylinders in the process of distilling tar. Calcareous spar and sulphur are disseminated through the pores of this substance.*

* To the east-south-east of the Coley-hill dyke in the line of its direction, a vein is found traversing Walker Colliery, and crossing the Tyne at Walker. This dyke is well defined. It occasions no alteration in the level of the coal strata, and its depth is unknown. It has been cut through by horizontal tunnels at four places. On each side of the dyke, *the coal is converted into coak*, which on one side, in some places, was found to be 18 feet thick, and on the opposite side upwards of nine feet. A firm, hard, and unbroken vein of basalt, on an average, about 13 feet thick, was in immediate contact with the coak on each side; and between these two veins lay nodules of basalt and sandstone, upwards of nine feet in thickness, imbedded in a cement of blue slate.

A dyke called the Cockfield dyke, which is 17 feet wide, underlies to

In Derbyshire, the Basaltic beds and veins are called Toadstone from their colour, and in Warwickshire, Rowleyrag, from a group of hills formed of it at the village of Rowley, near Birmingham.

The trap often occurs as at Rowley, in overlying

the south, and throws up the coal measures on that side 18 feet. The low main-coal contiguous to the basalt, is only nine inches thick, but enlarges to 6 feet at the distance of 150 feet from it. *The coal is reduced to a cinder*, and the sulphur is sublimed from the pyrites near to the dyke.

A dyke is seen on the banks of the Tees, a little below Yarm. It there passes into the newer red sandstone, and continuing its course in the same direction, is well known to traverse the north-eastern part of Yorkshire, near the still more recent formations of lias, and the sandstone of the inferior oolite, in the eastern Moorlands, in its way to the German Ocean. This dyke is highly interesting from its great length, and from the evidence which it affords by thus penetrating later rocks, that it must have owed its origin to eruptive forces, in action at a period long subsequent to the formation of the coal; a proof which yields a strong analogical presumption that the other dykes of the coal-measures are likewise subsequent, and not contemporaneous phenomena.

These circumstances render the course of this dyke, through the more recent formations, a matter of much geological importance. It may be traced from Berwick on the Tees in an easterly direction, near the villages of Stanton, Newby, Nanthorp, and Ayton. At Langbath ridge a quarry is worked in it; it passes south of the remarkable hill called Roseberry Topping, near Stokesly, and thence by Lansdale to Kildale. It may be seen on the surface nearly all the way in the above track. From Kildale it passes to Denbigh-dale end, and through the village of Egton-bridge, and hence over Leace ridge through Gothland, crossing the turnpike road from Whitby to Pickering, near the seven-milestone at a place called Sillon-cross on a high moor. Mr. Bakewell examined it at this place, where it is quarried for the roads, and is about 10 yards wide. From this place it may be traced from Blea-hill to Horwood dale, in a line towards the sea, near which it is covered with alluvial soil; there can be no doubt, however, that it extends into the German Ocean. It is a dark grayish-brown basalt, which turns brown on exposure to the atmosphere, and is the chief material for making roads in the district called Cleveland. The dyke enters the lias near Nanthorp, and the sand of the inferior oolite near Roseberry Topping.

masses, as if effused above the strata, forming tops to the mountains, and distinctly reposing on the coal measures. Mr. Bakewell states, that he observed in connexion with the basaltic cap of the Tinterston Clee (Shropshire), a vast fissure or dyke, more than 100 yards wide, filled with the same basalt that intersected the hill, cutting through the coal fields. It rises from an unknown depth, and seems to have forced a part of the coal to the surface. Where the basalt comes out in contact with the coal, it has injured its quality, and reduced it to a sooty state.

§ I. OF THE NATURE AND ORIGIN OF COAL.

There are three different substances to which the name of coal has been given :—1. Lignite or fossilized wood, in some places, retaining its texture very distinctly, and passing by a series of gradations from this state to that of jet. Bovey Heathfield, in Devonshire, affords a good example of this deposit; and similar beds may be found on the banks of the Rhine, between Cologne and Bonn; as also in the basaltic area of the north-east coast of Ireland.

2. Anthracite or stone coal, a substance destitute of bitumen, occurs on the continent, in mica-slate and other primitive rocks. In the transition slates of Derbyshire, anthracite also occurs. Carbonaceous matters of this kind can never be profitably worked, so as to become objects of statistical interest.

3. The proper coal measures, called the Independent Coal Formation, by Werner, from its occurring in insulated basins. This great carbonaceous deposit is interposed between the mountain

limestone, and old red sandstone below, and the saliferous or newer red sandstone above.

Coal is a peculiar compound of carbon, hydrogen, and oxygen, in which the first principle greatly predominates. A little azote is also generally present. Some coals, when distilled at a red heat, afford a considerable quantity of bitumen or tar, others, such as blind coal, afford none, and burn without flame. The bitumens, petroleums, and naphthas, contain more hydrogen, and less oxygen, than coals do.

Dr. Macculloch has shown, that the substances produced from wood exposed under pressure, to the action of fire, are not true bitumens or coal, as had been supposed by Sir James Hall, but forms of a peculiar compound, resembling indeed the bitumens in colour and inflammability, but essentially different in many respects, containing more oxygen than the true bitumens. He calls this artificial body, *bistre*, a name commonly given it by artists. The doctor's experiments discountenance the idea that fire has been the agent of converting vegetable matter into bitumen.

By a series of experiments on peat and various lignites, their gradual progress of bituminization was ascertained. In jet, the extreme term of the lignite series, no chemical difference from coal existed, except that it afforded acid in distillation, instead of ammonia, or volatile alkali, which is a product of true coal.

We have evidence indeed, that the action of water, on turf, or wood, is sufficient to convert them into substances capable of yielding bitumen in distilla-

tion. The same action operating during a longer period, may have probably produced a change on the brown coal of Bovey. From this to the harder lignites, surturbrand, and jet, the transition is so gradual, that water may possibly effect the bituminization in all these varieties; "nor is there aught in this change," says Dr. Macculloch, "so dissonant from other chemical actions, as to make us hesitate in adopting this cause. By the application of heat under compression, to jet, it seems to fuse into a substance like true coal." The incipient stage seems therefore the work of water, the final one, of fire. Whether these two agents have been conjoined by nature in her great coal formations, is altogether uncertain, and must be left to future inquiry. Certainly that hypothesis which traces the change to water alone, is the preferable. Had fire been an agent extensively or generally employed, it is difficult to conceive why it did not at the same time consolidate the shales and sandstones. The coal-districts exhibit no unequivocal tokens of igneous agency, except where they are traversed by whin-dykes. The great chemical argument appears to be, that the coal exhibits exactly the same results, as the most decided lignites, the process being merely further advanced. Iron pyrites is often disseminated in great abundance among the coal. I have examined with great care many specimens of coals of the purest quality, and have always found in them more or less iron.

However numerous and powerful the objections which may be offered against the vegetable origin of coal, it appears very difficult to contest it.

When we see the multitude of reeds filled and surrounded with sandstone, having their thin scaly bark, converted into a true coal, it is impossible to doubt of its vegetable origin. The same thing is true of the impressions, which are very frequently found in the slate-clay, completely reduced to the state of common coal. When, in the coal-measures, we observe the vestiges of vegetables becoming more numerous, in proportion as we approach the strata of coal, and as the formation becomes more carbonaceous, it is difficult to avoid thinking that they must have existed in a still greater quantity in the coal seam itself. If they are no longer perceptible there, it is owing to chemical agents, operating on these masses of plants, entirely decomposing them, and rendering their remains indiscernible. Plants *have* been there; but coal has replaced them. It is therefore natural to conclude that they have been transformed into this substance, especially as observation and chemistry concur to show the possibility of this transformation. But did woods, uprooted forests, and shattered trees produce the strata of pit coal, as they undoubtedly produced the beds of lignites found in so many places? This is not maintained. The vegetable matter that produced the coal was probably reduced to a pasty state, and elaborated by suitable agents amid the tepid waters of the primeval globe; in which semi-fluid form it was deposited in the earthy strata, where it is now found. The thin layers of coal, which though but one or two finger-breadths thick, are plane seams which reach to a considerable extent; the form of a great many of the ordinary

beds, whose opposite faces are perfectly parallel through a great space, refute the notion that these beds are merely heaps of trees promiscuously crowded together. It would seem rather that the coal has been semi-liquid at the moment of its deposition, and has then settled down as a precipitate or deposit. How otherwise can we account for those narrow fissures observed in Lusace, less than an inch thick, which are filled with coaly-matter, constituting true coal-veins? How could these small veins of coal, which sometimes traverse the sandstone strata, have been introduced, unless their substance had been originally fluid? How otherwise could the numerous bituminous schists which occur in the coal-measures get impregnated with so great a quantity of liquid coaly matter? How could the earthy beds which serve as roofs or walls have imbibed that same substance? Finally, how otherwise could the substance of the coal-seams have acquired that homogeneous substance and texture, as well as the faculty of cubical division into something like crystalline forms?

What kind of vegetables have chiefly concurred to the formation of coal? Judging from the remains found in the coal measures,—the only good ground of judgment, we must conclude that they were reeds, ferns, and other aquatic plants, similar to those that have left their impressions in the slate clays. It deserves to be remarked that reeds have always left a coaly impression on the shales and sandstones; but in the impressions of other plants, the colour is no deeper than in the adjoining stone.

On contemplating the impressions of such deli-

cate leaves and ferns, with their parts in perfect preservation, and nowise crumpled; on observing the reeds quite straight and in their primitive position, we conclude that all these plants could not have been much drifted and tossed by the waters, but that they now lie near their native bed. In what degree the action of sulphuric acid, or sulphate of iron, producible from the pyrites so generally distributed in coal measures, has contributed to the conversion of wood into coal, we have no satisfactory data to determine. Mr. Hatchett has furnished some ingenious speculations on this subject.

The quantity of ammonia which coals afford in distillation, has led some chemists to suppose that they are at least in part, a product of the decomposition of animal bodies. It is possible that these may have contributed slightly; but when we see several plants, such as the cruciform family, yield ammonia, we need not press the argument for its animal origin. The bituminous schist of Thuringia which contains so great a quantity of fishes crushed and even converted into a species of coal, and which is occasionally used for fuel, demonstrates the possibility of that carbonaceous transmutation. The coal of Pomiens in Dauphiny yields on distillation a large quantity of ammonia. It contains numerous sea shells, and even bones of marine animals, to which probably some of its substance is due. But as this does not occur in a genuine coal-formation, it cannot be regarded as a true pitcoal. It is clear, however, that animal matters are convertible into something very like coal.

That carbonaceous matter is also an original constituent of the mineral kingdom, is sufficiently obvious from the existence of plumbago, or nearly pure carbon, in the middle of gneiss, mica-slate, and other primitive rocks. Anthracite or stone coal, is found disseminated in the quartz and barytes of the metallic veins of Kongsberg; localities where it cannot be ascribed to the decomposition of vegetables. Besides what a vast magazine of carbon, is locked up in limestones, under the form of carbonic acid?

To the vegetable origin of the coal-measures, the great quantity of carbon contained in them appears a formidable objection. In spaces of no large extent, 30, 40, or even 60 strata or seams of coal, occur separated by layers of sandstone and schistose clay. Could this succession have been possible had the plants remained in the place of their growth? Whence could proceed at regular intervals that quantity of herbaceous plants, which has produced the 61 seams of the coal basin of Liege?

We must bear in mind, however, the vigour of vegetation that prevailed in these latitudes on the antediluvian globe. Of this fact, the fossil vegetables now found in our coal measures are ample testimonials.—See Book III. Chap. iii.

The phenomena of basaltic veins and beds, penetrating all the strata, even the chalk or cretaceous limestone, prove that during the whole interval from the creation to the deluge, the antediluvian ocean, under which these basalts were generally protruded, must have experienced violent agitations, which would throw up the waters over its shores, and

sweep down with the reflux, the prolific vegetation into their sandy bed. Here the high temperature of the seas, indicated by the fossil remains of crocodiles and turtles now found in our shell strata, would rapidly decompose the submersed plants, into a bituminous paste, where it would be soon covered with a layer of sand. In this way we may imagine how coal-measures even to the extent of Liege or Newcastle, may have found successive beds of vegetable material, during the period that elapsed between the creation and the deluge. We must not however limit to that interval the conversion of the buried vegetable bodies into coal; for unquestionably that coal might go on progressively ripening during many subsequent ages by aqueous percolation.

One of the richest deposits of coal that is known, forms the nearly continuous series of coal basins placed in a belt about 150 miles long and 6 miles broad, which crosses the north of France, containing the coal-mines of Valenciennes, Condé, Mons, Namur, Liège, &c. They produce annually more than 70 millions of quintals of coals, worth 30 millions of francs, and they employ 35 thousand colliers. Their beds have a direction similar to that of the band; they are of an uniform nature, accompanied with the same sandstones and schistose clays. They present similar foldings, and every thing indicates that they are parts of one whole, which extends beyond the Rhine to Osnabruck. The coal-mines in the neighbourhood of Newcastle, put out annually more coal than the whole of the above French district, namely, 2,355,000 London chaldrons according to Mr. Winch.

M. Villefosse, in his *Traitè de la Richesse Minerale*, estimates at little more than double the above amount the product of all the coal mines of England; a quantity certainly too small.

Germany contains several great deposits of coal, particularly in Thuringia, and its neighbourhood, in Saxony, Bohemia, and Silesia. Coal is very rare in the north of Europe, in Sweden and Norway; countries so rich in mines of other kinds. Spain and Italy possess almost none.

Coal exists in China in considerable quantity; and perhaps there is no country in the world, richer in coal than the provinces of Chensi, Chansi, and Petcheli, says M. Panser, in his Mineralogy of the Chinese Empire.

Mr. Maclure informs us that to the west of the Alleghanys, there is a formation of coal most extensive and regular. Its beds are from one to six feet thick; and are placed to the number of 20 or 30 over each other. They alternate with sandstones, schistose clay, and clay containing iron ore.*

* That the mountain limestone beneath the coal of the English mines, has been a marine formation, is perfectly evident from the nature of the imbedded shells. But the vegetable organic remains of the coal-measures themselves indicate that their strata have been deposited out of the sea, most probably under a fresh-water lake. The inferior limestone stratum may therefore have been raised by subjacent expansive force, before receiving the succession of vegeto-carbonaceous, sandy, and clayey deposits. But since the coal measures are covered in many places with marine strata to a considerable depth, the sea must have once more inundated that marsh land, converting it into an estuary. Successive inundations consentaneous with the successive submarine eruptions of trap, which are known to have occurred about that geological period, seem capable of explaining the phenomena of alternate deposits, and of accounting for the introduction among the coal measures

As the origin of our coal-fields must obviously be sought for in antediluvian vegetation, the reader will find the subject amply discussed in Book III. Chap. iii. of this work.

Lignites which are manifestly bituminized wood, hold an intermediate place in the gradation between vegetable matter and pit-coal. They have the fibre of the former, with the jetty lustre and fracture of the latter. Some lignites closely resemble peats in their chemical characters, others seem to graduate into perfect coal. It is therefore the geological position in the coal measures, that defines this combustible. Whatever is found in the strata above the magnesian limestone has been called a lignite. Coal is in fact to vegetable matter, what adipocire is to animal; the completion of the chemical change, in which the fibrous structure disappears. Lignite has generally a woody aspect; coal always that of a rock.

Lignite appears in three distinct localities; in alluvial soils, among traps, and under stratified rocks. Marine remains occur in all the lignites; showing their beds to have been formed by drifted wood under the sea; whereas they are very rare in true coal. Hence one is led to infer that the coal-basins have been originally lakes liable to alternate inundations; whence the alternate deposits of vegetable

themselves, of a few sea fossils, the bottom of the estuary being of course nearly level with the ocean. That such eruptive violence accompanied and followed the coal formations is placed beyond a doubt, by the multitude of dislocations and dykes, which traverse the coal-fields in every direction, and by the basaltic caps thrown over them, as at the Corstorphine-hills near Edinburgh.—*Macculloch—Journ. Science*, No. 44. p. 312.

matter, clay and sand, afterwards converted into coal, shale and sandstone, under great superincumbent pressure, possibly of the ocean.

Lignites occur abundantly in oolite, passing into coal at Carpona, and in the island Veglia, where they are excavated for the use of the Trieste steam boat. The lignite mines of Buda in Hungary are remarkable for the supply of fuel which they afford. It seems to be admitted by Brogniart that the supposed coal of the south of France is a lignite formation, occupying a higher part of the series than the last examples, and lying in the green sand deposit.

There are extensive mines in Provence, about Marseilles and Toulon, where twenty-eight beds are wrought. The principal deposit at Cologne is 30 feet thick; the locality also of the pulverulent lignite so valuable in painting. Lignites abound at Soissons, Epernay, Laon, St. Paulet, and some other places in France. To the lignite above the chalk, are supposed to belong those immense deposits found in the middle of the Alps, and those of Styria mined for fuel.

The lowest deposit of lignite found in the oolite is more akin to pit coal, than those found above the chalk and among traps. Oysters and ammonites have been found among them; and in the trap coal-field of Brora in Sutherland, there are, besides these shells, madreporites, the spines of echini, belemnites, terebratulæ, and other fragments belonging to mytili or cardium. Lignite, in some of its lowest deposits, forms regular beds of coal, sometimes of considerable thickness; and where these alternate with the shales, sandstones, and limestones of the

series, the superficial aspect is so much like that of the regular coal, that we cannot be surprised at its having been mistaken for that deposit.*

§ II. OLD RED SANDSTONE.

This sandstone forms the bottom lining of the great primitive basins in which the coal measures lie. It occurs sometimes as a breccia in large fragments, sometimes a puddingstone, sometimes a finer sandstone finally passing to an earthy mass, of porphyritic quality. The visible fragments all belong to primitive rocks, granites, mica-slates, clay slates, porphyries, quartz, &c. which resemble in nature the rocks of the neighbouring mountains. Its prevalent and characteristic dark red colour forms its

* An interesting discovery has lately been made near Scarborough in Yorkshire, at Gristhorpe Bay, of a large deposit of fossil plants, presenting many varieties hitherto undescribed. They occur in the strata called *coaly grit* by Mr. William Smith, a pseudo-coal field below the *cornbrash*, being far above the geological place of the true coal measures. The plants lie in horizontal strata, those of the same species being together, as if the localities of each had been extremely limited, and as if they had been suddenly swept down by a great torrent of water. Some are very small and young; some large, and others in fructification. Several of the species are of considerable magnitude and beauty, nay even in admirable preservation. The plants are principally ferns, different from those of our coal measures, but congenerous with many now existing in tropical regions. Already 50 species have been distinguished; a prodigious variety of filices compared with those now vegetating in our climate. At Cloughton, in a somewhat similar formation, ten miles distant, there are several other kinds, totally distinct, offering a number exceeding the whole now living in the island of Great Britain. So that these northern regions, must in those ancient times, have presented as numerous and diversified a display of ferns, many of most luxuriant growth, as the wilds of Southern Africa, now do of heaths. Some of the specimens are perfectly pliant and combustible. There are also many varieties of the tree ferns, which constitute such numerous and splendid ornaments of tropical forests.—*Dr. Peter Murray—Jameson's Journal, September*, 1828.

best distinction. No important minerals appear to have been procured from this stratum; nor are organic remains usually found in it. The old red sandstone frequently forms mountains between 2 and 3 thousand feet above the level of the sea; in height yielding therefore only to the primitive and transition chains of this island, on the sides of which rocks indeed it reclines. On the borders of the forest of Dean, this formation exceeds 2000 feet in thickness, and is interposed between the transition and carboniferous limestone.

§ III. CARBONIFEROUS OR MOUNTAIN LIMESTONE.

This limestone is so named from the elevations which it attains; it is called metalliferous also; and encrinal or entrochal from its organic remains. The title of first flœtz limestone, given it by the Wernerians, which signifies horizontal, is very inapplicable, since its strata are highly inclined, following the concave contour of the old red sandstone, though not quite so steep.

The texture of carboniferous limestone is usually imperfectly crystalline, and sufficiently close grained, and hard to afford marbles susceptible of a durable polish. Its prevailing colour is gray; but it has other shades,—yellow, blue, and sometimes black. Some of its beds are so pure as to contain 96 per cent. of carbonate of lime; but by foreign admixture, it passes into magnesian limestone, ferruginous limestone, bituminous limestone, and fetid limestone. Its beds are commonly very thick, extending in a continuous series many hundred feet in depth, with their interstitial seams of clay. Occasionally

it exhibits alternations of various heterogeneous rocks, particularly toadstone, grit and shale. It is a leading feature of this limestone to be full of caverns and fissures. All the considerable caverns in this island occur in this rock. Rivers flowing across its range are often suddenly engulphed, and pursue to a considerable distance a subterranean course; and the hills composed of it, exhibit often rocky dales and mural precipices. Much of the most picturesque and romantic scenery of England is formed by carboniferous limestone.

It is the great repository of the English lead ores; as those of Northumberland, Durham, York, Derbyshire, and Somersetshire. The following metallic minerals have been found in it; ores of antimoniated lead, copper, zinc, and iron.

ORGANIC REMAINS.

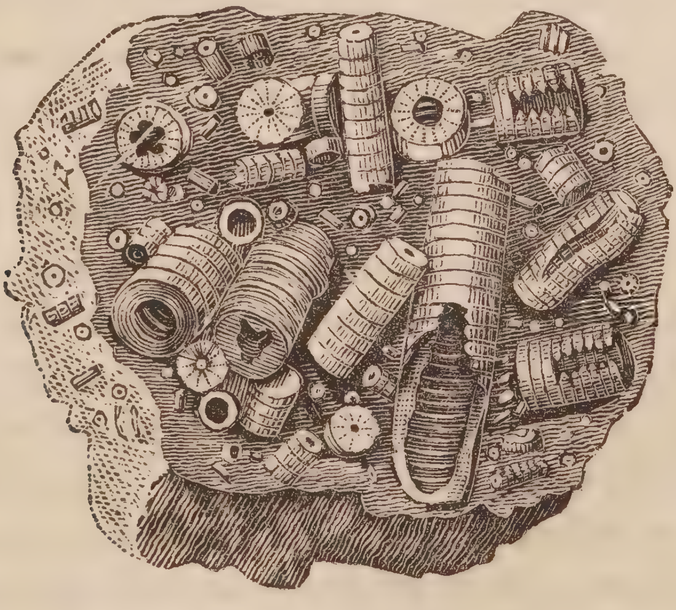
The animal remains preserved in the carboniferous limestone are strongly distinguished from those in the superior limestones, the oolitic and the lias, and belong in a majority of instances to entirely distinct families. These are generally common to this and the transition limestone, marking thereby a decided distinction between it, and the limestones of the supermedial class of rocks. Vertebral animals are still very rare; many species of *testacea* or shell fish, now begin to appear, but they all belong to a very few genera; while the zoophytal families (*polyparies,*)

Encrinites.

particularly encrinites and corallites exist in the greatest profusion. Some vertebræ of fish, sharks' teeth, many singular palatal tritores, and the radius of a *balistes*, exhibit this formation as the lowest sepulchre of vertebral animals.

Of the *crustaceous tribe*, trilobites occur in this formation, as in the transition limestone; but the species seem to be distinct. Among the univalves we may enumerate the following genera :—

Ammonites, nautilites, orthoceratites, euomphalus, cirrus, nerita, helix, turbo; among bivalves, modiola, mya, cardium, terebratula, spirifer, producti, a few echini, See Plate I; and among encrinites, posteriocrinites, platycrinites, cyathocrinites, actinocrinites, rhedocrinites. All the species of encrinites here are distinguished from those occurring in the lias and more recent beds, by the thinness of the *ossicula* forming the cup which contains the viscera. *See Miller on Encrinites.*



Encrinal Limestone or Marble.

From the profusion of these species this limestone has been often called encrinal. The coralloid remains are caryophyllea, turbinolia, astrea, favosites, tubiporus, retepora.

This limestone formation rises in England to upwards of 1000 feet above the sea level; whence

its title of Mountain limestone. It is generally surmounted, however, by the margins of the superjacent mill-stone grit. Its thickness frequently amounts to more than 900 feet. The strata, like those of the superjacent grit and coal measures, are often highly inclined; this happens especially in the south-western counties, where they sometimes become quite perpendicular.

This formation is subject to extensive dislocations or faults. For instance, at the foot of Ingleborough is a subsided mass of coal-measures, at the base of the whole limestone series; a dislocation, therefore, seems to have taken place equal to the thickness of the collective mass. Mr. Farey describes the western edge of the Derbyshire limestone tract, as abutting against a similar *fault*, which must exceed 900 feet.

§ IV. MILL-STONE GRIT AND SHALE.

The coal-seams usually rest on a series of beds which are called mill-stone grit and shale. The former is merely a coarse grained sandstone, consisting of particles or fragments of quartz agglutinated by an argillaceous cement. The distinctive mark of this species of coal sandstone is its great induration. It is evidently a rock mechanically formed from the detritus of pre-existent masses. Rounded particles of felspar are occasionally seen in it. This grit alternates with shale, especially in its under part. Occasional beds of both limestone and coal are also found here. The coal-seams are few, thin, and of bad quality. The limestone resembles the mountain formation.

The locality of satin spar seems to belong to the shales of this series. Bitumen has also been found in the same; as well as petroleum, mineral caoutchouc, and asphaltum. Vegetable impressions analogous to those of the coal strata are observed in this series; and in its limestone beds, a few marine shells similar to those in the subjacent limestone. The mountains formed by the upper edges of this stratum, rise to 2 or 3 thousand feet above the level of the sea; and the thickness of the beds sometimes exceeds 120 fathoms. Their inclination conforms to that of the coal-measures, and the faults are common to both.

§ V. COAL MEASURES.

These consist of beds of coal, slate-clay or shale, and sandstone alternating with one another in different ways, and repetitions. Those of coal although characteristic of the formation suite, are however the least numerous; and sometimes they are wanting entirely over a considerable space. The sandstones form most commonly the principal mass of the series; but occasionally the slate-clays, or rocks participating of both the clay and sandstone texture, predominate.

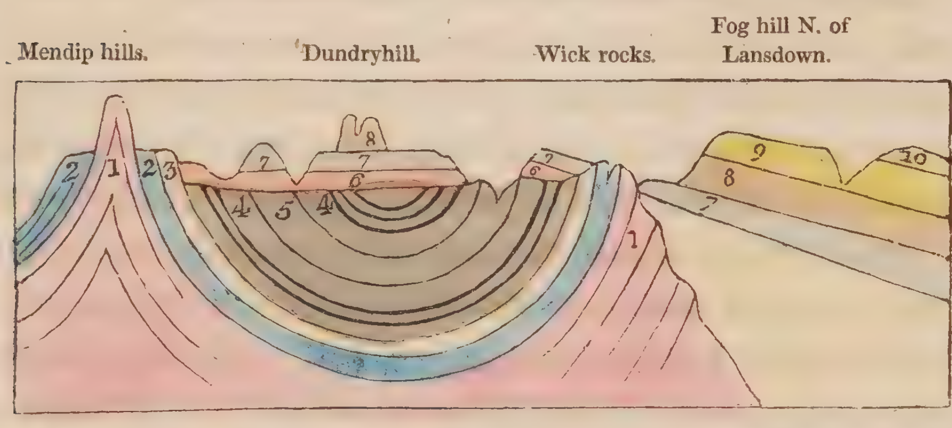
The order of superposition among these several beds, is not very uniform. It is, however, observed in many mines, that the seams of coal, are usually included between layers of shale; that further from the coal the grain of the shale becomes coarse, and passes into sandstone. It is found that sandstone forms more frequently the floor, if horizontal, of the coal strata, and that shale constitutes their roof.

Immediately above the coal this shale roof is black, mixed with carbon, and replete with vegetable impressions; but on receding from the coal, the carbonaceous matter and the impressions diminish, the grain enlarges, and sandstone results. In coal mines generally the layers of coal and those of rock are repeated several times in the same order, and in nearly similar thickness, presenting a very remarkable alternation. The number of strata of coal which occur above each other, in the same series, is often very considerable. At Anzin near Valenciennes, a pit less than 100 yards deep passes through 50 layers small and great; at Liege, 61 have been ascertained; the single mountain of Duttweiler near Saarbruck includes 32; at Newcastle, the Killingworth pit within 230 yards, traverses 25. The strata of sandstone and shale are considerably more numerous than the coal-seams. The slate-clay is known in different collieries by different names; black or blue metal, slate, clunch, cleft, bind, &c. The sandstones of the coal measures are usually gritty, micaceous, and tender; affording freestones for buildings, whetstones, grindstones, and flag-stones for pavements, even roofing slates; and they have various local names, as plate, post, pennant.

Clay iron-stone, in beds or courses of nodules, is common in the coal fields, yielding on an average about 30 per cent. of metal. Indispensable as this is to all the arts which bring comfort to man, with what providential kindness is its ore here associated with its flux and fuel,—the limestone and the coal, whose combined action alone can make it useful! Most

justly, therefore, does Mr. Conybeare say, "that it can hardly be considered as recurring unnecessarily to final causes, if we conceive that this distribution of the rude materials of the earth, was determined with a view to the convenience of its inhabitants."

SECTION OF A COAL BASIN.



1, 1, Old red sandstone. 2, Mountain limestone. 3, Millstone grit. 4, 4, Coal seams. 5, Pennant or coarse sandstone. 6, New red sandstone, or red marl. 7, 7, Lias. 8, 8, Inferior oolite. 9, Great oolite, 10, Cornbrash and forest marble.—*Coal-field south of Malmsbury.*

We shall conclude our account of the coal-measures with an example of the superposition of their strata. See foot note.*

* The following is a table of the different beds bored through at Bradley colliery near Bilston in South Staffordshire, beginning with the lowest, and terminating with the surface bed.

Geological Name.	Local Name.	Thickness in Feet.
1. Coal,	Heathing coal,	Unknown.
2. Slate-clay,	Clunch,	4
3. Shale,	Table batt,	2
4. Coal,	Coal,	0½
5. Shale,	Hard batt,	1
6. Clay-ironstone,	Iron stone,	3
7. Slate-clay,	White clay	2
8. Slate-clay,	Blue clay,	0½
9. Clay,	Short earth,	1½
10. Coal,	Main coal,	25¼
11. Shale,	Black batt,	2½

The inclination of the strata which the basin shape bestows on the coal measures, is an arrangement most beneficial to man. Thus the successive seams rise on its edges to the surface or near it; and thereby disclose the mineral treasures concealed beneath, which would otherwise have rested invisible and unknown. By the sloping position, many of the beds are not only brought within the reach of the miner, but the whole become more easily worked and drained. There is one device, however, in the coal measures, which, to a superficial thinker will appear a defect in the fabric, though it be essential to their usefulness; I allude to the dislocations of the strata, usually called faults, (see page 159,) because they seem defects, or, at least, put the miner to fault in his search after the coal. These intersections, whether by slips or whindykes, act as valves to the porous

Geological Name.	Local Name.	Thickness in Feet.
12. Clay-iron-stone,	Iron stone, . . .	$0\frac{2}{3}$
13. Slate-clay, .	Blue binds, . . .	5
14. Shale, . .	Batt, ...	4
15. Coal, . .	Flying reed, . . .	5
16. Shale, . .	Batt, ...	4
17. Slate-clay, .	Blue clunch, . .	9
18. Slate clay,	Ditto, containing 4 thin iron-stone beds,	12
19. Sandstone, .	Grey rock, . . .	1
20. Slate-clay, .	Clunch, . . .	$1\frac{1}{2}$
21. Sandstone, .	Peldon, . . .	2
22. Sandstone, .	Grey rock, . . .	3
23. Slate-clay, .	Blue clunch, . . .	18
24. Sandstone, .	Grey rock, . . .	3
25. Slate-clay, .	Blue clunch, . . .	24
26. Red sand, .	Sand, . . .	30
27. Soil, . .	Soil, ...	2
	Total,	$169\frac{1}{2}$

seams, or as floodgates to arrest the diffusion of the subterranean springs. By these natural dams, the water which might inundate the whole, or, at least, entirely submerge the richest deposits of the centre, is confined to a single compartment, from which it is in most cases practicable to drain it.

The eruptive forces, moreover, in creating these mounds to the waters, have, at the same time, upheaved many strata, which, had they been left to follow their natural slope, would have been sunk to inaccessible depths. A coal formation is thus parcelled out into cubical fields, each of which is complete in itself, and to a certain degree independent. But for these slips, the rains which fall profusely on the lofty basset-edges or out-crops of the strata, would percolate down through them, and convert the basin into a subterranean lake, which no human power could possibly drain. Similar eruptive intersections exist in many other strata, and they every where act as cisterns, or even sometimes as pumps, raising in syphon channels a copious supply of spring water to the surface. These safeguards of mines are, therefore, not confined to coal basins, but are providentially distributed through every important mineral bed.

In contemplating the effects of any mighty convulsion on his terrestrial abode, man is apt to feel appalled, and to regard the operation as altogether irregular, fortuitous, and uncontrolled, because its magnitude and complexity mock his pigmy conceptions of power. Yet no one will doubt that the primordial erection of the great mountain strata and table lands was the result of wise design, if he study

their conformation, and reflect that this earth could not otherwise have become the abode of animation. Nor can we meditate upon the manifold advantages derived from the upheavings of the secondary strata without seeing in them also, traces of Him "who is wonderful in counsel, and excellent in working."

The naturalist always contemplates the members of an animal, in reference to its way of life; and can deduce from even a few bones, many of the functions which it performs in this scene of being. For every part he finds a special purpose, nor does he ever dream that the slightest bump or curvature of a bone is made in vain. He seeks the conditions of its existence in the catenation of its frame. Why then is the philosopher to suppose that the framework of the earth itself, should not also have *its* conditions of existence as definite as those of an inconsiderable bird or insect, nay, incomparably more refined and complex, since it must be in harmonious relation not only with every order of organic existence, but with the ocean; the atmosphere; heat; light; and the solar system itself? It well becomes us, then, in surveying the various chambers of the terrestrial edifice, if some few apartments should appear in our eyes rudely fashioned, or in disorder, to abstain from all presumptuous judgments, humbly to confess our ignorance, to investigate with diligence and docility, trusting eventually to recognise beauty and wisdom, in what seemed at first sight, deformity and confusion. Final causes which the zoologist must consult at every step, ought not then to be neglected by the geologist. Unfortunately they have been so often abused and

misinterpreted by ignorant, though perhaps well-meaning speculators, that the man of science has become chary of their employment, and pusillanimous in their vindication. But final causes, under inductive restraint, will ever form the noblest and most delightful species of knowledge, comprehending in its sphere, the correlation of the most general physical and moral truths.

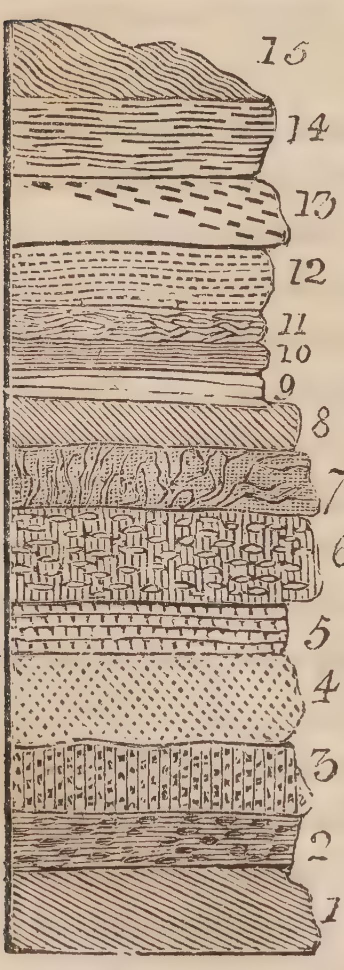
CHAP. IV.—SUPERMEDIAL STRATA.

The appearances of the great coal strata, lead us to believe them formed by alternate earthy and vegetable deposits, in some immense lakes or estuaries of the antediluvian earth. The progress of our inquiries, proves the globe in those times to have been the frequent subject of mighty convulsions, which have disturbed the strata over an extent prodigiously greater than the explosions of modern earthquakes and volcanoes could give us reason to conceive. It is certain that the sea must have participated in the violence under which the solid earth has evidently suffered. Irruptions of the waters over the land, would unquestionably occur at every new crisis of the eruptive power so conspicuous in the coal-measures and basaltic formations.

Thus we can understand how the surface of the coal basins came to be covered in several places with a series of sandstones, or of limestone-strata, replete with marine shells.

During all this period also, a series of deposits was forming under the sea, in a determinate order of superposition on its channel. These deposits are characterised by peculiar orders of organic remains.

It is known to the naturalist, that shellfish live in colonies; each colony preferring a peculiar ground or locality; and that in general, quartzose sands are shunned by them, as unfavourable to their production. Hence many districts of our ocean-floor are destitute of shells, whilst others are covered with a vast congeries of them. It is ascertained, that if fowls be deprived of access to calcareous matter, they lay eggs unprovided with shells, and eventually lose the faculty of laying them altogether. In like manner, it would seem that there are districts of the sea so deficient in calcareous matter, that molusca cannot there elaborate their calcareous mansions, and consequently shellfish cannot exist. These suggestions will serve to explain many peculiarities observable among the secondary formations.



Over the extensive regions where the coal-measures themselves are absent, the old red-sandstone, or the mountain limestone, constitutes, generally speaking, the stratum that represents the place of coal in the geological series, or plane of superposition. On this principle, it is said that the secondary rocks are superior to the coal formation, though no coal should really lie immediately below them.

Order of Superposition of English Strata, according to Messrs. Conybeare and Phillips. See Fig. on margin.

1. Magnesian limestone and red marl.—2. Lias.—3. Inferior oolite.—4.

Great oolite.—5. Cornbrash and Forest marble.—6. Oxford or Clunch clay.—7. Coral rag.—8. Kimmeridge clay; Oak-tree of Smith.—9. Portland limestone.—10. Iron or Hasting's sand.—11. Blue marl.—12. Chalk marl with green sand.—13. Lower and upper chalks.—14. Plastic clay and sand.—15. London clay.

The supermedial class of rocks as exhibited in England has been divided into four groups of strata.

I. Formations between the coal strata, and lias, including,

1. Magnesian limestone, corresponding in position to the zechstein, the copper-pyritous slate, and rauchwacke of Germany; and to much of the Alpine limestone. It is the first flœtz limestone of Werner. Between this series and the coal, there is observed in Germany, a great deposit of red-sandstone and conglomerates, called the red dead-layer *(rothe todte liegende)*, because destitute of the metals found in the beds above it. This is the older or first flœtz sandstone of Werner. Much of the sandstone of Southern Africa belongs to this formation.
2. New red-sandstone, or red marl, corresponding to the variegated sandstone of Germany. Rock salt and gypsum occupy this locality.

I. MAGNESIAN LIMESTONE.

1. This magnesian limestone is called the newer, to distinguish it from the same mineral associated with the carboniferous limestone. The two differ in their organic remains, and in this upper one containing extensive beds of calcareous conglomerate. The magnesian limestone has a granular sandy structure, a glimmering lustre, and a cream-yellow colour. It often forms large concretional and botryoidal masses; as large as a cannon ball, which are grouped together like chain-shot. It is used for building, and has a pleasing tint. When calcined, it forms a mortar lime. In agriculture it is

injurious, unless sparingly used. It is poor in organic remains. The principal range of hills of this rock in England, extends from Sunderland to Nottingham. They never rise more than 600 feet above the sea; are round-topped, and overlie the coal at Cullercoats in Northumberland. A whin-dyke which here traverses the coal, does not enter into the magnesian limestone; wherefore the latter deposit is judged to be of more recent formation. At Hart, near Hartlepool, it was bored to the depth of 52 fathoms, without getting through it. On the east of the coal-field in Derbyshire, it is about 50 fathoms thick. The inclination of its beds is generally trifling, being conformable to that of the upper strata, except where it is placed over coal, whose slope it follows. The stratification of this rock is exceedingly distinct, and the separate layers of stone seldom exceed the thickness of a common brick. Its character as a soil is very indifferent; and its springs are not abundant.

To the geological era or locality of superposition of the magnesian or old alpine limestone, belong the pyritous schists of many districts of Germany, which contain fossil remains of the saurian or lizard family, called monitors. Throughout the countries of Thuringia and Voigtland adjoining to Hessia, as far as Franconia and Bavaria, beds of marly and bituminous schist extend, which Werner regards as the lowest of the first flœtz sandstone. Being besprinkled with grains of argentiferous copper pyrites, the ore is mined in several places for the two metals, although it is very poor, yielding scarcely two *per cent.* of

copper. Humboldt says that a similar stratum is found in several parts of America. The German miners call it, naturally enough, the dead bed, because it affords no proper veins of copper. Above this cupriferous schist, lie the calcareous strata, known in that country by the name of zechstein, and comprehended by the French under the class of older alpine limestone; they contain shells and zoophytes, of the earlier kinds, such as entrochi, anomiæ, &c. The gypsum, with its subordinate *sal gem*, rests over these limestone beds, and is surmounted in its turn, by sandstone covered with a second gypseous formation unaccompanied with salt. Over this gypsum, another limestone, of more modern date reposes, analogous to the Jura. In its calcareous beds, are those great caverns, which were found filled at their first discovery, with bones of bears and other carnivora, to be afterwards described.

Thus we perceive that these strata of bituminous schist are among the most ancient of any which contain the exuviæ of organized bodies not testaceous. From among their tabular slabs, the vast multitudes of fossil fish were extracted, which have rendered the cantons of Mansfeldt, Eisleben, Ilmenau, and other places in Thuringia and Voigtland, so celebrated among those who collect and describe petrifactions.

Many of the fish are pyritified, in consequence of which, they are subject to rapid decomposition on exposure to the air; and have thus been destroyed. They belong to species unknown in the living state among ichthyologists.

The first account of the stone-casts of the reptiles found in these strata was published by Spener in the *Miscellanea Berolinensia*, so far back as 1710. His specimen was found in the mines of Kupfersuhl, 3 leagues from Eisenach, 100 feet beneath the surface. The bones were in some degree metallised, like the most part of the fish of the same strata. The second published impression, likewise announced to be a crocodile, was the subject of a letter from Henry Link to the English geologist, Woodward, in 1718. It is from the same place, and in the same kind of stone as the preceding. The third is engraved in the treatise *de Cupro* of the famous Emanuel Swedenborg. It came from the mines of Glücksbrunn near Altenstein, where it was found in 1733. The fourth was extracted in 1793 from the mines of Rothenbourg near the Saale in the territory of Halle, 264 feet under ground. It is at present in the Royal Cabinet of Berlin. These four specimens, found in beds of the same nature, present certainly animals also of the same species, as is obvious from the similarity of form and size of all the common parts, and especially of the spine, the tail, and a portion of the limbs. These may therefore be all employed to reconstruct a complete individual, by attaching to the common trunk, the parts insulated in each specimen.

The form of its head, its teeth wholly sharp, and the magnitude of the vertebræ of its tail, are alone sufficient to show that it was an oviparous quadruped; without recurring to its posterior limbs, which still more strongly confirm this decision. The head has some resemblance to that of a crocodile; but its

very short muzzle, makes it more different from a gavial, than from any other species of lizard reptile. Even the head engraved by Spener, indicates of itself the genus of the animal. Had it been a crocodile, it would have had at least 15 teeth on each side in its lower jaw, and 17 or 18 in the upper, which would have extended to beneath the middle of its orbits. It has, however, only 11, which go back no further than under the anterior angle of the orbit. This is the character of one of those numerous species which have been crowded together by Linnæus under the name of *Lacerta Monitor*. This first feature, once recognised, is confirmed by all the rest.

Spener conjectures that the length of his animal must have approached to three feet; those of Swedenborg and Link had nearly the same size, which agrees with what the monitors of the most ordinary species usually attain; such as the land and river monitors of Egypt, that of Congo described by Dandin, those of the East Indies, &c.

§ II. RED MARL.

2. *Red marl, or new red sandstone,* called occasionally *Red rock* or *red ground.* It stretches with little interruption from the northern bank of the Tees in Durham, to the southern coast of Devonshire, covering a great extent of country. It appears sometimes as a reddish marl or clay, sometimes as a sandstone, and at others as a conglomerate of different rocks, cemented by marl or sand. It is remarkable for containing gypsum beds, and the great rock-salt formation of England. Coal

strata are seen to dip beneath it. The colour varies from a chocolate to a salmon hue. The red marl is noted for its rhombic fissures. No organic remains whatever have yet been observed in any of the rocks belonging to this formation.

The red marl and its associated magnesian limestone, form the lowest of the nearly horizontal strata which occupy the southern and eastern counties of England; the strata on which these repose are unconformably placed with regard to them, and rise from beneath them often at very considerable angles, into lofty mountains, skirted by the red marl, which occupies the extended planes at their base.

The agitation of the waters would thus seem to have washed that pulverulent deposit down from the sides of the elevated rocks of carboniferous limestone, old red sandstone, transition slate and greenstone, strewing it over the hollows.

Near the head of the western branches of the Trent, the great central plain of the red marl unites with that which occupies almost the whole of Cheshire, the southern part of Lancashire, and the northern part of Shropshire; watered by the Dee, the Weaver, and the Mersey. The valleys of these rivers are covered by the red marl formation, and the central valley that of the Weaver, affords throughout its course abundance of saline springs, containing above 25 per cent. of salt. Gypsum is also abundant. At Northwich in this vale, an extensive deposit of rock-salt has been found, consisting of two beds, together about 60 feet thick. These are supposed to be large insu-

lated masses of salt about a mile and a half long, and 1300 yards broad. There are other deposits of this saline mineral in the same valleys, but of inferior importance. A section of the workings at Northwich is given below.*

The salt works of Droitwich in Worcestershire are situated in the south-west portion of this great marly plain.

	Feet.	Inches.
* 1. Calcareous marl on surface, . . .	15	0
2. Indurated red clay, ...	4	6
3. Indurated blue clay with sand, . . .	7	0
4. Argillaceous marl, ...	1	0
5. Indurated blue clay, ...	1	0
6. Red clay with sulphate of lime irregularly intersecting it,	4	0
7. Indurated brown clay with grains of sulphate of lime interspersed, ...	4	0
8. Indurated brown clay with sulphate of lime, crystallized in irregular masses, and in large proportion, .	12	0
9. Indurated blue clay, laminated with sulphate of lime,	4	6
10. Argillaceous marl, ...	4	0
11. Indurated brown clay laminated with sulphate of lime,	3	0
12. Indurated blue clay with laminæ of sulphate of lime,	3	0
13. Indurated red and blue clay, . . .	12	0
14. Indurated brown clay, with sand and sulphate of lime, irregularly interspersed through it, . .	13	0
The fresh water finds its way through holes in this stratum at the rate of 360 gallons per minute. It has its level 16 yards from the surface.		
15. Argillaceous marl, ...	5	0
16. Indurated blue clay with sand, and grains of sulphate of lime,	3	9
17. Indurated brown clay with a little sulphate of lime,	15	0
18. Indurated blue clay with grains of sulphate of lime,	1	6
19. Indurated brown clay with sulphate of lime, .	7	0
20. The first bed of rock salt, . . .	75	0
21. Layers of indurated clay with veins of rock salt running through them, ...	31	6
	226	9
22. The second bed of rock salt which has been sunk into from 105 to 108 feet, . . .	108	0
Total depth of workings, . .	334	9

The districts occupied by the red marl formation are in general destitute of any eminences exceeding 400 or 500 feet. Its thickness appears to be very variable. At Durham, pits have been sunk in it fruitlessly for coal, to the depth of 708 feet, without passing through the beds of this rock; while at Puckle church in Gloucestershire, shafts have been sunk from the lias beds to the coal measures, through this formation, with 153 feet of boring. The red marl between Darlington and Yarm, about 10 miles distant, a little on the south of east, near its junction with the magnesian lime, is at least 120 fathoms thick. The dip of the beds of this formation is generally inconsiderable, and in a direction conformable to that of the lias, and other superjacent strata.

Some of the richest land of England lies in the range of red marl. It is uniformly fertile for wheat, barley, beans, peas, and is distinguished for the goodness of its cyder apples. Several experienced land surveyors have said that the best tracts of land to be met with, occur in this stratum. The trefoil springs up every where of its own accord. Water cannot be procured without sinking through the marls into their subjacent sandstone and conglomerate beds.

§ III. OOLITIC SERIES.

This series includes all the strata between the red marl, and the iron sand. It is the great repository of the best architectural materials that England produces; consisting of oolitic limestones, calcareous sands and sandstones, argillaceous and

argillo-calcareous beds, which alternate with one another generally in the same order; that is an argillo-calcareous formation, is surmounted by a calcareo-siliceous sand, over which lie many beds of oolitic limestone. Three of these systems comprehend all the beds between the saliferous or new red sandstone, and the iron sand. Each of these systems reposes on a very thick argillo-calcareous formation, which always constitutes a very distinct line of demarcation, and prevents the possibility of mistaking them or confounding them together. The oolitic rocks of each system generally form a distinct range of hills, separated from that of the other systems, by a wide argillaceous valley. Hence we may represent in a synoptical view, the whole suite, as divided into the lower, middle, and upper oolitic systems.

1. *Lower Oolitic System.*	Great argillo-calcareous formation of lias and lias marl, the base of the whole series.—Calcareo-siliceous sand, sustaining and passing into the inferior oolite.—Numerous oolitic strata occasionally subdivided by their argillaceous seams; including the cornbrash, Forest marble, schistose oolite, and sand of Stonesfield, and Hinton, the great oolite and inferior oolite.
2. *Middle Oolitic System.*	Great Oxford clay, (clunch clay of Smith), which divides the oolites of this system from the next. Calcareous sand and grit. Oolitic strata associated with the Coral rag, (pisolite of Smith).

3. *Upper Oolitic System.*	Argillo-calcareous formation of Kimmeridge and the Vale of Berks, which divides the oolites of this from the next system, (Oak-tree of Smith). Calcareous sand and concretions, (Shotover hill and Thame). Oolitic strata of Portland, Tisbury, and Aylesbury. Argillo-calcareous Purbeck strata, between the iron-sand, and oolitic series.

The term formation is employed to distinguish these three oolitic systems, which are separated by vast intervening argillaceous deposits. These formation suites, seem to have resulted from the gradual and successive action through a long period, of similar causes undisturbed by any violent change of circumstances. As these causes produced at one time argillaceous, at another arenaceous, and at a third calcareous and oolitic deposits—alternations several times repeated—they prove the very unstable equilibrium of the terraqueous fabric in those ancient epochas.

Each of these beds is characterised by its peculiar organic exuviæ, and very often even the minutest subdivisions of the strata may be thus distinguished. Remains occur of many extinct genera of oviparous quadrupeds, more or less akin to crocodiles, and monitors, but apparently inhabitants of salt water only, as also, various vertebral fishes, testaceæ of every description, coralloid zoophytes, encrinites, &c.

These formations occupy a zone in England, on an average, nearly thirty miles broad, stretching

across the island from Yorkshire on the north-east, to Dorsetshire on the south-west.

The extensive chains of the Jura mountains, between France and Switzerland, are principally composed of lias or gryphite limestone and an oolitic series, in close analogy with these formations in our own island. The principal varieties of the oolite or Jura limestone; are, 1. A compact gray marble; 2. A granular oolite, the latter occurring abundantly in the Tyrol, in the valley of the Adige below Trent, and occasionally in the Salzburg mountains. The former prevails in Switzerland, and generally throughout the Alps.

The lias, like all the other formations in the Alps, is destitute of our alternating beds of clay, but holds its position between the oolite and new red sandstone. In the central parts of Germany, the lias stretches from the Rauche Alpe (a continuation of the Jura chain), through Wurtembourg to Nurembourg, Gotha, Wurtzbourg, and Cobourg, occupying the greater part of the lower country between the mountains of the Black Forest and Vosges, and the Böhmer Wald and Thuringer Wald. The tracks of these formations in England, France, Germany, and Russia, may be regarded as parts of a continuous series of deposits which cover the great central basin of Europe.

§ IV. LIAS.

This formation consists of thick argillaceous deposits, the base on which the whole oolitic series reposes. Their superior portion, embracing two-thirds of their total depth, consists of beds of a deep

blue marl. It contains only a few irregular and rubbly limestone beds. In the lower part, the limestone beds are more frequent, and assume the peculiar aspect of lias, namely a series of thin stony beds separated by narrow argillaceous seams, giving the quarries of this rock, a striped and ribband-like appearance at a distance. In the undermost beds of this limestone, the argillaceous partings often become so thin as almost to disappear, a circumstance observable in the lias tract of South Wales. Beds of blue marl with irregular calcareous masses, generally separate these strata from the red marl of the subjacent new red sandstone formation. The limestone beds towards their centre when freest from admixture, contain fully 90 per cent. of carbonate of lime; the rest is alumina and iron.*

When the limestone beds come in contact with the alternating strata of clay, more alumina gets introduced into the mineral. The lias limestone is particularly characterised by its dull earthy aspect, and large conchoidal fracture. Its colour varies

* Westbury cliff on the west bank of the Severn, Gloucestershire, illustrates the lower beds of the lias formation.

	Feet.
White lias,	10
Blue shale passing into marl stone,	10
Black shale with iron-shot fissures,	12
Green siliceous grit, highly micaceous, and containing plenty of bones, well known by the name of the bone bed,	1
Black shale,	2
Green grit,	0
Black shale,	2
Greenish marlstone decomposing into balls,	18
Red marl of the new red sandstone formation.	

in different beds from light slate-blue or smoke-gray to white, the former shades belong to the upper, the latter to the lower layers of the formation. The blue lias contains much iron, and affords a lime capable of setting under water. The white is susceptible of a fine polish, and may be employed in lithography. It must be distinguished, however, from the lithographic stone imported into this country from the continent. This comes from the quarries of Solenhofen, and is of much more recent formation, or stands higher in the order of superposition.

The slate-clay or shale with which the lias alternates is of a gray-brown or black colour, it is frequently bituminous, and readily divides into plates as thin as pasteboard. The lias is never of a variegated hue like common marble, nor brecciated, neither does it take brilliancy or depth of tint by polishing. It sometimes exhibits dendritical appearances (Cottam marble). The irregular beds consist of fibrous limestone and cement stones (septaria), so called from being used in making Hydraulic mortar. When they are large and flat, these septaria are called girdles. Along the Whitby coast these girdles have afforded a partial protection to the shale, occasioning a number of grotesque insulated masses, which often turn red on exposure to the air.

The lias is nearly destitute of metallic or earthy minerals, except iron-pyrites which is very abundant. By the acidification of its sulphur the argillaceous strata acquire that efflorescence of the aluminous sulphate, which is so extensively worked at Whitby.

To the same pyritous decomposition, must be ascribed the spontaneous inflammation often observed in the cliffs near Charmouth in Dorsetshire.

Organic Remains.—The organic remains contained in the lias are peculiarly interesting. They afford more animals of a higher order (viz. of the vertebral class) than are contained in the catalogue of any other formation, excepting perhaps the Stonesfield beds of calcareous slate, in the great oolitic series about to be described.

In this class we have first to notice the remains of two very remarkable extinct genera of oviparous quadrupeds, evidently belonging to the same group with the great natural order *Lacerta*, or lizard; but differing most essentially in structure from all the genera at present known to exist, and in such a way as must have fitted them to live exclusively in the sea. They appear, therefore, to bear the same relation to living lacertæ, that the cetacea (whale tribe) bear to other mammalia, and form a division of the order lacerta to which the name *Enalio-Sauri* (marine lizards or fish-crocodiles) may be conveniently applied. The investigation of their comparative anatomy, or rather osteology, is very interesting. It has laid open various new links in the chain of animated nature. See the end of this section.

LIST OF LIAS FOSSILS.

3. The Whitby alum shale contains also abundant bones of the ichthyosaurus and plesiosaurus.

4. Bones and palates of the turtle have been found in this formation.

5. Fish of several species also occur in its strata.

6. The radius of a species of balista is of common occurrence.

7. There are some crabs, of the crustaceous tribe.

8. Among testaceous animals we have species of ammonites, nautilites, belemnites, helecinæ, the trochus, modiola, unio, cardita, terebratula, spirifer, gryphea, ostrea, pecten, plagiostoma, lima, plicatula; but the most characteristic shells, are the ammonites Bucklandi, gryphea incurva, and the plagiostoma gigantea. See Plate II.

9. Echinus, a variety of cidaris papillata.

10. Encrinites. Many species of pentacrinite occur in the upper beds of the lias formation.

11. Corals—madrepora turbinata.

The vegetable remains consist of fossil wood, sometimes charred and occasionally silicified. Gigantic reeds resembling *arundo donax*, are found in the sea cliffs opposite High Whitby. Trunks and branches of fossil trees, the bark and softer parts of which have been changed into jet, are frequently met with in the alum shale; and leaves and impressions like those of the palm, occur in the sandstone and iron-stone.

The lias formation stretches across from the coasts of the German Ocean in Yorkshire to those of the Channel in Dorsetshire. The best places for studying this stratum are the cliffs of Whitby in Yorkshire, those of Fretherne and Westbury on the estuary of the Severn in Gloucestershire, of Watchett in Somersetshire, of Aberthau in Glamorganshire, and of Lyme in Dorsetshire. The lias generally forms broad and level plains at the foot of the oolitic range of hills. It has been remarked that the argillaceous formations in most cases, constitute low tracts in the present configuration of the earth's surface; a circumstance which may be ascribed to their offering less resistance, after deposition under the antediluvian ocean, to the sweeping action of the agitated waters. They must have also suffered a similar operation from the rains, ever since they were brought to the day. Near the Mendips, the lias sometimes occurs on the brow of tolerably steep escarpments, but its maxi-

mum elevation does not amount probably to five hundred feet above the level of the sea. This may also be regarded as its thickness. The inclination of the strata is generally very small, not exceeding 40 feet in the mile, which conformably with all the strata that range across the island, from north-east to south-west, is in a south-easterly direction.

As a soil it is usually cold and tenacious, fitter for pasture than tillage. In Glamorganshire, however, it bears very fine wheat; and the marl of the rag, or gray lias, is reckoned the richest in the country.

The springs are generally thrown out by the marl above the lias, near its junction with the lower beds of the sand that underlie the inferior oolites; and it is therefore uncertain, to which formation the flow of water should with most propriety be referred.

Completely within the district of the lias marls, water can be had only by sinking to the bottom beds.

GREAT ANTEDILUVIAN AMPHIBIA.

I shall annex to the present section, a somewhat detailed account of this interesting order of antediluvian animals, all long since extinct, which occur in the lias or the adjoining mineral beds. A few words may be premised on the great cetaceous fishes (the whale tribe). From an investigation of their fossil remains, and from a skilful comparison of them with the osteology of their living types, M. Cuvier draws the following conclusions.

Thus is more and more confirmed the proposition already deduced from the examination of fossil shells,

that not only the productions of the dry land have been changed during the convulsive revolutions of the globe, but the sea itself, the principal agent of the most part of these revolutions, has not preserved the same race of inhabitants; that when it formed in our neighbourhood those immense calcareous rocks, replete with shells at present almost all unknown, the great *mammifera* which it nourished were not those which people it at the present day; and that in spite of a strength commensurate with their enormous size, they have not been able to resist the turmoils of their own element; in the same way as the elephants, hippopotamuses, and rhinoceroses, the most robust of quadrupeds, fell victims on the surface of the earth to corresponding violence.

The bones of crocodiles form a very interesting group of animal remains. They are by no means rare in the deeper and more ancient secondary strata; and although they differ in species, they all belong to the long muzzled sub-genus, which Cuvier calls *gavials*.

In the year 1758, Woller and Chapmann found on the sea-shore in the Whitby alum-slate formation, the bones of an animal like a crocodile. The drawing which they gave in the Phil. Trans. vol. L. shows a contorted spine, 9 feet long, and a head somewhat out of place, 2 feet 9 inches in length. The head narrows anteriorly, not suddenly, but by degrees, as in the crocodiles of Altorf and Honfleur, into a pointed snout, which was covered in certain places with the remains of the lower jaw. At these places there appeared in both jaws, large

sharp-pointed teeth, placed alternately, and closely crossing each other; but where the under jaw had been carried away, the teeth of the upper jaw were also removed, showing only their deep sockets placed at the same respective distances as the teeth themselves, that is to say, three quarters of an inch asunder. The enamel of the teeth was well polished.

At high water, the sea rose 5 or 6 feet above this skeleton, and had tossed up sand and pebbles which had defaced it a good deal, destroying the strata which had originally covered it. It is now in the Museum of the Royal Society. Camper pronounced this fossil to have been a whale; but a whale has no teeth, and this animal had teeth in both jaws. It may probably belong, says M. Cuvier, to the newly discovered fossil animal, *Ichthyosaurus.*

In December 1824, there was observed in the face of a steep cliff, near Whitby, part of the head of a large animal, standing out from the surface of the alum-shale, several yards above high water-mark. After several days' labour, attended with considerable peril, the whole of the bones were got out of the rock; forming a nearly complete skeleton of a crocodile. Most of the bones of both the hind legs, with fragments of those of the fore legs, were distinctly recognised. At the same time, the appearance of portions of the scaly crust of the animal, arranged in rectangular compartments, as in the crocodile, made it easy to determine the family to which the animal had belonged. It is figured in the Edin. Phil. Journ. vol. XIII. p. 76. The length of the animal seems to have been about 18 feet.

The form of its head allies it to the *gavial* crocodile. The teeth are small and very numerous, and arranged in straight lines as in the Ichthyosaurus, but not in the bent or curved form, like those of the living crocodile. The vertebral column and bones of the pelvis resemble in structure those of the Nilotic crocodile.

The crocodiles of Franconia were not known so soon as those of England, but in genus they are not subject to the same uncertainty. The rock containing them, is described as a calcareous stone, or bad marble of a gray colour, replete with ammonites and other ancient shells. The quarries are near the small town of Altorf, now belonging to the kingdom of Bavaria. The strata are referred to the middle oolites. The heads belong to the genus crocodile, but the species is uncertain.

The gangue in which the crocodile bones of the Vicentin are imbedded does not resemble the preceding; though it also belongs to the shell-limestone formation of Jura (lias and oolites). One of the most complete and undoubted fossil crocodiles both as to genus and species, is that of Monheim, discovered by Sœmmering.

There are few countries more celebrated among naturalists, and collectors of petrifactions, than that which extends along the banks of the Altmuhl, one of the tributaries of the Danube, towards Pappenheim and Aichstedt. Here the numerous quarries of a whitish calcareous schistus which are worked into paving stones for the floors of apartments, perpetually furnish casts of fishes and crustaceous animals, entirely unknown to modern Germany,

and most probably to living nature. Among these are also some very curious reptiles, such as the pterodactyles, or wing-toed animals, which we shall describe afterwards.

These schists have acquired a general celebrity from their employment in lithography, a purpose which they answer better than any other stones. They belong to that prolongation of the chain of the Jura mountains, which after opening a passage to the Rhine at the fall of Schaffhausen, extends into Germany, as far as the banks of the Mein near to Cobourg.

The valley of the Altmuhl has very precipitous sides. On these it is easy to observe through a height of 200 feet, the constituent range of strata. The calcareous schists occupy the summit. They are rich in fishes, in *crustacea*, reptiles, and even star-fish, but destitute of other shells, except two species of *tellines*, and some small ammonites. These strata repose on a considerable mass of dolomite or magnesian limestone, of which M. Von Buch gives a very interesting history in the Journal de Physique for 1822. It is not stratified, and presents hardly any where traces of petrifactions. Of this dolomite, and its covering schists, there are none very near at hand, in the whole chain of the Jura. They begin to appear only between Donawert and Nordlingen. The dolomite itself extends to the north much farther than the schists, and it is in its masses that the famous bone-caverns are hollowed out, of which we shall afterwards treat. Under it are beds of grayish-white limestone, compact, dull, with a scaly fracture, rich in ammonites,

which furnish enormous building-stones; and last of all there is a brown-gray or gray-limestone, of a fine grain, the basis of all the hills of this canton.

The most celebrated of these slate quarries is that of Solenhoffen, in the very valley of the Altmuhl, a little below Pappenheim. The fossil crocodile which we are now to describe, was found at a little distance from this place. It was discovered at Daiting, two leagues from Monheim, enclosed between two plates of a schistose marly limestone, yellowish-gray, spotted red or yellow with oxide of iron, and mingled here and there with fragments of quartz, delicately veined, of a blackish colour, and crystallized. It was accompanied with a cast of the tail of a small fish, and remains of an insect.

The bones of the crocodile are browner than the stone itself. They still contain, by M. Gehlen's analysis, some animal matter, with a notable proportion of phosphoric acid.

The larger of these stone slabs, 3 feet long, and 15 inches broad, contains the head, the trunk, and the tail of this animal, from end to end, very little deranged, along with a hind foot almost entire, detached from the trunk and incrusted at some distance. Scaly parts are mingled with the bones.

We there see the upper face of the lower jaw armed with 25 or 26 teeth on each side, with its two branches separated at an angle of 30°. Of the upper jaw we see the palatal surface, along with the covering bone and other parts of the skull together, but a little detached, along with the snout. The series of the vertebræ 69 in all, is not deranged except towards the tail. A single glance will con-

vince the comparative anatomist that this fossil skeleton resembles a small *gavial* crocodile more than any other known animal.

It has on the whole the proportions, the number of parts, the form of the snout, of the feet, of the teeth, &c.; and in fact some attention is requisite to discover the differences; which however will be found to be quite specific. It has ten vertebræ more than any crocodile known to naturalists. These are in its tail. From this, and several other distinctive marks, it is styled by Sœmmering and Cuvier the *Ancient Crocodile*, with oblong cylindrical muzzle, under teeth alternately long and short, and the thigh bones double the length of those of the leg. The above animal was fully 3 feet long. The length of its head was nearly seven inches, and of its tail nearly 19. It is very remarkable that the tail is no longer in proportion to its body, notwithstanding its having ten vertebræ more than the little *gavial* which is most akin to it. A fossil crocodile of a similar kind, but in much worse preservation, was found long ago at Boll in Wurtemberg, and is now in the cabinet of Dresden.

But a more interesting specimen of this fossil animal has been recently exhumed from the stone quarries near Caen in Normandy. In this district, below the chalk, and the great ferruginous sand which serves as its basis, is a bed of blue marl which begins to show itself at Havre, and rises more on the other side of the Seine, at Henqueville, between Honfleur, and the Vaches Noires. In this bed, have been found near Havre, bones of a crocodile. Under this stratum there are vestiges of our

Portland limestone, and lower still, the madrepore bed which is called in England, coral rag. Under this are found beds sometimes 300 feet thick, of another blue marl analogous to that of Oxford, which forms the Vaches Noires, whence the crocodiles were dug, and the species of reptile that Mr. Conybeare has called *plesiosaurus*. Between this marl, and the stone of Caen, there are two other beds equivalent to the cornbrash and forest marble of England. The latter must be the bed replete with corals, alluded to by M. Magneville, president of the Academy of Caen, under which alone is found the Caen rock. Beneath it, we have another bed of blue marly stone, the counterpart of the lias of England, which rests on the red sandstone. M. de Labeche who has given a good account of this district in the *Trans. of the London Geological Society, 2d series, vol. I.* thinks that this lias of France contains bones of the ichthyosaurus like that of England.

It is however certain that this crocodile of Caen as well as that of Monheim, those of Honfleur, and several others which remain to be mentioned, belong to the great assemblage of beds which French geologists, have agreed to call the *Jura* formation, and the English, oolites.

This crocodile does not seem to have been rare in this part of the world, at the period when it lived, for within the very few years that attention has been bestowed on this kind of fossil monuments, the remains of at least ten individuals have been collected.

The fragment belonging to this species, which

has excited most attention, was found at the end of the year 1817, in that portion of the stone beds of Caen which occupies the right bank of the river Orne, in the quarries of a small village called *Allemagne*, about a league to the south of the city of Caen. It lay about 50 feet below the surface of the soil, under which these quarries are worked. Among several very curious blocks exhibiting various parts of the skeleton, one contains the skull. The oblong snout was imbedded in the neighbourhood, along with the vertebræ, the ribs, the bones of the legs and feet, and the scaly armour of the animal, all in good preservation. These belong to a *gavial*, different alike from all the living, and fossil species hitherto discovered. The entire snout was at least 30 inches long.

There are some crocodile remains in the Jura itself, in its most compact strata, which are very similar to marble in hardness, and susceptibility of a fine polish. They are accompanied by several species of tortoises.

"The presence of an animal," says Cuvier, "such as the crocodile, apparently belonging to fresh water, in such beds is a very remarkable circumstance. It is the more deserving of notice, as it is there accompanied with several tortoises, all equally inhabitants of fresh water. This fact joined to several others of which we shall speak, proves that there existed dry lands irrigated by rivers at an exceedingly remote epoch, and long before the successions of those tertiary mineral formations, which exist in the neighbourhood of Paris." But may not these strange species of crocodiles, have been adapted to

live in the sea, as well as their companion tortoises?

A rich collection of the bones of two unknown species of gavial crocodiles, was made near Honfleur and Hâvre, and transmitted to the Museum of Natural History in Paris. These bones belong to a mineral formation, anterior to the strata which furnish the bones of even the most ancient quadrupeds, such as are found in the gypsums round Paris; for these gypsums repose on the shell limestone, which rests on the chalk, that covers the crocodile bed.

The most considerable of these fossil remains, is an under jaw nearly complete. It presents more characters than are necessary to determine a species, and to distinguish it from the existing *gavial.* In the same strata, fragments of another jaw are found far liker the gavial's.

Another jaw-bone, closely resembling that of the *gavial,* has been found on the left bank of the Yonne. This must have belonged to a crocodile $17\frac{1}{2}$ feet long.

Two other crocodiles, one with a long and the other with a short muzzle, have been detected among the fossil bones from Honfleur.

Crocodiles have also been discovered under the chalk formation in the ferruginous sands of England; in the chalk itself at Meudon; and immediately over the chalk in the lignites and plastic clay of several districts.

Teeth and bones of a crocodile, have been detected in the lignites (wood coal) above the chalk, and under the coarse limestone and plastic clay of Auteuil near Paris.

It is indeed very probable that beds of lignite exist above the coarse limestone, the *calcaire grossier* of Brogniart, which are consequently of more recent formation.

M. Cuvier has shown that if the species of crocodiles now existing be more numerous than was believed, the fossil species present also a great variety. At least six perfectly distinct ones may be reckoned, which differ no less from the living crocodiles, than they do from each other. These are the species of Monheim, the two species of Honfleur, and that of Caen; the whole of which four belong to the sub-genus of *gavials;* and the species of Montmartre and Argenton, whose sub-genus appears to be rather that of the crocodiles, or the caymans.

Our knowledge on this head is very interesting, since it proves that crocodiles have been subjected to the same law as the mammiferous animals, and that their species have not resisted the catastrophes which new modelled the exterior crust of the globe. But the most remarkable truth of which we have here the first intimation, is that the different classes of vertebral animals have not the same geological graves, for the fossil monuments of reptiles are deeper seated, and consequently have been interred at much earlier periods than the land *mammifera.*

Thence, till the last epoch but one, there has always subsisted in our regions some species of crocodiles, and in considerable abundance. A few occur even in the diluvial and superficial strata, in which so many carcasses of elephants and other great quadrupeds have been buried; if we do not sup-

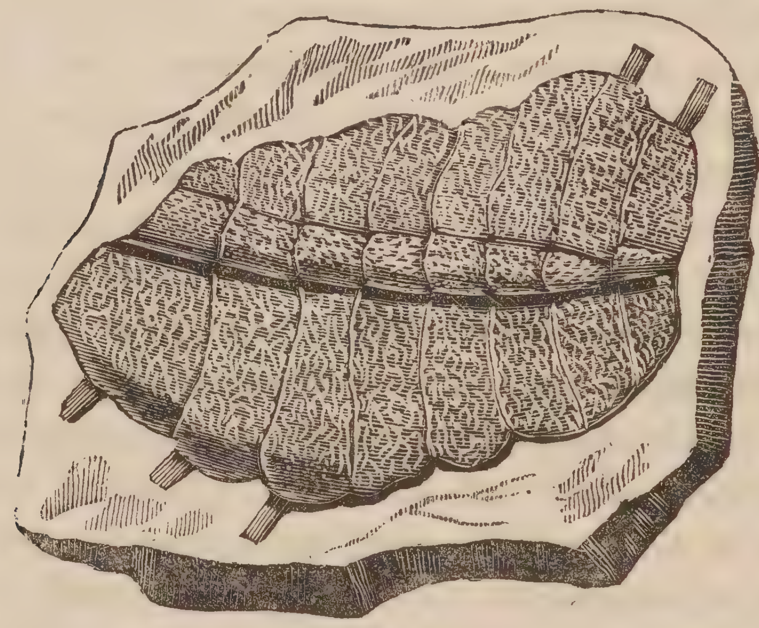
pose that the small number of fragments collected at Brentford have rather been transported thither from the debris of some deeper mineral bed.

It must nevertheless be admitted that the bones of crocodiles are extremely rare in these diluvial soils.

Cuvier has not seen them either in those immense collections of bones of all sizes that have been made in the Val' d'Arno, or in those of Germany, or in any of the French deposits. "This circumstance," says he, "must appear the more extraordinary, as crocodiles live at the present day in the torrid zone with the elephants, the hippopotami, and all the other genera which have furnished those bones. I am, however, just now informed that some have been recently found in the diluvial beds of the Val' d'Arno." This want or rarity of crocodile remains in diluvial soils should excite no surprise whatever, for the rising flood of waters which killed the land quadrupeds, would not prove fatal to the amphibious crocodile. Hence as these two classes of animals did not die together, they could have no common place of sepulture. The crocodiles would in fact hold by their favourite element at the retiring of the waters, and come thus to be transferred from rivers to the ocean. Many would probably be destroyed in the catastrophe, and a few might die from age, whose remains may have been left on the land when the waters were drawn off into their new reservoirs.

The variety of living tortoises is so considerable, as to make it difficult to decide whether a fossil tortoise belongs to an unknown species or not.

On the left bank of the Aar, a little way north of the town of Soleure, are numerous quarries of Jura limestone, which was certainly formed under the sea, yet in which the remains of tortoises (*emydes*) and crocodiles occur. A shield was found 24 inches long, and 20 broad. Similar specimens have been dug out of the ferruginous sandstone of the county of Sussex; in the soft sandstones of Dordogne and Switzerland, strata reckoned superior to the chalk formation; and in the clay strata of the Isle of Sheppy.



The above figure represents a fossil tortoise of the trionyx tribe, found in the gypsum quarries of Aix. The shield is seen to have lost a portion of its margin. The vertebral plates form a ridge in the middle of the back, like the *trionyx carenata* of Geoffroy. The trionyx of Java and the Ganges is the only one possessed of a similar shield, though there are differences sufficient to distinguish this from every living species now known.

Remains of sea turtles are found in the neighbourhood of Maestricht, in those celebrated quarries of a kind of coarse chalk of a sandy appearance, excavated in the mountain of St. Pierre, and they

are promiscuously mixed with such a variety of marine productions and bones of gigantic *saurians* (lizards and crocodiles) as have rendered this mountain famous in geology.

It now remains to treat of the most celebrated fossil reptile, one which occasioned most controversy, having been taken at one time for a crocodile, at another for a *saurian* of some other order, and lastly for a cetaceous animal, or even for a fish.

Its bones have been hitherto found only in one canton of inconsiderable extent, in the hills which border the east or west side of the valley of the Meuse in the environs of Maestricht. The gangue is a very tender calcareous stone. This limestone bed is at least 489 feet thick. In many parts of it, nodules of silex are found, which along with the circumstance of the stone changing by degrees into chalk, a few leagues up the valley of the Meuse, proves the mass to belong to the chalk formation. It contains moreover the same fossils as the chalks of Meudon, and the other portions of the Paris basin; namely, sharks' teeth, gryphites, belemnites, and ammonites. All these shells are found along with the bones, in the lower parts of the mass which are also the most tender. The upper parts are harder, and contain more madrepores, so that none of these are collected unless when some fragments fall down from the top of the mountain. Several of them are converted into silex.

The numerous marine products with which this rock is filled are generally very well preserved, although they are rarely petrified, and the greater part of them have lost only a portion of their animal

substance. The most bulky and remarkable are the bones of an extraordinary animal, whose skull has been found entire. The lower jaw exhibits fourteen teeth on each side, all conformable in construction to the teeth of monitors; but the monitors have only 11 or 12; the crocodiles have 15, which are very unequal; the present teeth are equal or nearly so. The iguana's teeth are considerably more numerous. In those teeth there are large and pretty regular holes, to the number of 10 or 12. There are 5 or 6 in the iguana's; from 6 to 7 in the monitor's; in the crocodiles there are a great many small and irregular ones; but in a dolphin there are only 2 or 3 towards the end of the jaw. The whole composition of the lower jaw bone, in fact, indicates more numerous relations with the monitor, than with any other of the saurian tribe, and excludes the *cetacea*, which, like the land *mammifera*, have each side of the lower jaw in a single piece. The teeth in the palate alone prove that the fossil head did not belong to a crocodile or a cetaceous animal, for neither of these animals has palatal teeth. The coronoid process of the fossil jaw is a distinct bone, corresponding to a supplementary bone along side of it.

Though this fossil remain approaches more to the monitor than to any other animal, yet it has some peculiarities.

The crocodiles, monitors, safe-guards, and dragons of La Cépède, have palates devoid of teeth. The iguanas, the anolis, and the ordinary lizards participate with several serpents, batracians (frog tribe), and fishes, in this singular armour in the palate. Accord-

ing to Cuvier the head of this fossil animal serves to rank it between the monitors and the iguanas. But what an enormous size it has in comparison of any of the monitors and iguanas known! None of these living animals have probably a head longer than 5 or 6 inches; and that of the fossil in question is nearly 4 feet! In zoology, when the head, and especially the teeth and jaw-bones are given, nearly all the rest may be inferred, at least as far as essentials are concerned: hence there is no difficulty in classing the vertebræ when the head is once ascertained. The fossil seems to have belonged to an aquatic and swimming animal, somewhat like the crocodiles, using its tail as an oar from right to left, but not from above downwards like the *cetacea*. Several of its vertebræ have been found and described; particularly at Siechem. The spine of the animal was composed of 133 vertebræ, constituting a length of 21½ feet. This number is just about double of what the crocodile has, namely 68; but it agrees very well with the monitor's, in which there may be counted from 117 to 147.

As the jaw-bone was 4 feet long, the animal must have had a total length of about 26 feet, and its head approached to one-sixth of the whole, a proportion similar to that of the crocodile, but very different from the monitors, whose head forms hardly one-twentieth of their length. The tail is ten feet long, somewhat less than the half of the total length. It is therefore shorter than in the crocodile, in which animal the tail exceeds by one-seventh the length of the rest of the body, and it is much shorter than in the monitors, whose tail is one-half longer than the

body and head together. The extreme shortness of the bodies of the Maestricht vertebræ is what renders this tail so short. The animal must have been very robust, and the breadth of its tail must have formed a very powerful oar, enabling it to work its way through a turbulent ocean. There is besides no doubt from all the other remains which accompany its bones in the quarries, that it was a marine animal. All the ribs that have been found are round like those of lizards, and not flat as in crocodiles.

"Undoubtedly it will appear strange to some naturalists, to see an animal surpass so much in dimensions the *genera* to which it is most akin in the natural order, and to find its remains mixed with marine productions, whilst no other *saurian* (lizard) seems now to live in salt water; but these singularities are very inconsiderable in comparison of so many others presented in the numerous monuments of the natural history of the ancient world. We find a tapir of the size of an elephant, and the megalonyx of the sloth tribe, as large as a rhinoceros. What is there astonishing therefore in finding in the animal of Maestricht a lizard larger than a crocodile? But we shall soon see several other lizards of far greater dimensions."

It is peculiarly important to remark the admirable constancy of the zoological laws, which govern every class and every family. "'I had not examined," says Cuvier, "either the vertebræ or the limbs, when I was occupied with the teeth and the jaws; and a single tooth in fact announced every thing. When once the genus was determined by means of it, all the rest of the skeleton fell spontaneously

into its place, without trouble or hesitation, on my part. I cannot too much insist on these general laws, or the bases and principles of the methods, which in this science as in all others, possess an interest far superior to that of any individual discovery, however striking it may be. M. Conybeare has recently proposed for this fossil animal of Maestricht the name of *Mosasaurus*, which may be adopted till a generic name more descriptive of its characters be found."*

Another strange reptile has been discovered by M. de Sœmmering in the environs of Monheim, which he calls Lacerta Gigantea, and which M. Cuvier considers as a new subgenus intermediate between the crocodiles and monitors. He styles it *Geosaurus.* The bones were found at a depth of 10 feet, a few yards from those of the crocodile formerly mentioned, by some miners employed in digging the granular iron ore, which fills the fissures of the beds of the calcareous schistus. Enveloped in a bank still more marly, and softer than where the crocodile was impasted, these bones were not so well preserved; and it was difficult to disengage certain parts, so as to recognise their characters. Its head was only about one-fourth the size of that of the Maestricht animal, and therefore the term gigantic is not appropriate.

The *Megalosaurus* is a very great species of reptile, nearly akin to the preceding, discovered in the beds of oolite of Stonesfield near Oxford by the Rev. Dr. Buckland. It appears allied to the sau-

* Cuvier. Ossemens Fossiles, Tom. V. Part II. p. 337.

rians and crocodiles. If any animal deserve the title of gigantic it is the present species. Its thigh bone, 32 inches long, would of itself indicate, according to the proportions of a monitor, a total length of more than 48 feet, and if some thigh bones be found 4 feet and upwards, as has been asserted, its length would be still more prodigious. But its tail was probably not so long in proportion. By comparing it to the crocodile construction, it would still be more than 30 feet long.

" A philosopher who does honour to geology by precise and consistent observations, as well as by the steadiest opposition to random hypotheses, Professor Buckland, made this discovery several years ago, and I saw the fragments of the fossil at his residence in Oxford in 1818. I even delineated some of them there ; but he since had the complaisance to send me the memoir which he is about to read on this subject to the Geological Society of London. From this manuscript I derive the principal materials of the present article."*

These bones were discovered at Stonesfield, in a mineral bed to be afterwards described.

This fossil animal certainly surpassed the greatest crocodiles that are known, approaching in size to a small whale. From the incisor form of its teeth, there is no doubt that its disposition was exceedingly voracious. Every thing that accompanies its remains in the quarries where it lies buried, indicates its marine nature. We there find immense numbers of nautili, ammonites, trigoniæ, belem-

* Cuvier—Ossemens Fossiles, Tom. V. Part II. p. 344.

nites, some teeth of sharks and other fishes, various bones of fish, and remains of one or two species of crabs. Among these innumerable marine fossils, there are always some long bones which appear to have proceeded from long-legged birds of the order Grillæ, and even two fragments of jaw-bone of didelphus or opossum. It was not to be supposed that so enormous an animal could have been confined to a single locality, and accordingly fragments of it have been found in some other parts of England.

Mr. Mantell of Lewes in Sussex, has discovered megalosaurus' bones of enormous dimensions, and among others, fragments of thigh bones, the largest of which is 22 inches in circumference, whence Mr. Mantell concludes that its length must have been about 54 inches. The fragments of the bones of the metacarpus or metatarsus (bones of the instep) are so large, that M. Cuvier would have taken them at first sight, for those of a great hippopotamus. Along with these bones of *megalosaurus*, Mr. Mantell found bones of crocodiles, of tortoises, *plesiosaurus*, cetaceous fishes and birds.

These Stonesfield remains are found in a bed of calcareous sandy slate, the greatest thickness of which does not exceed 6 feet, and which lies in the upper part of the third or lowest division of the oolitic rocks; being nearly connected with the forest-marble, and interposed between the superstratum of cornbrash, and substratum of the great oolite of Bath. Its place among the continental equivalent formations, is between the central and

lowest strata of the Jura limestone. In working the quarries at Stonesfield, the men descend by vertical shafts, through a solid rock of cornbrash and stratified clay, more than 40 feet thick, to the slaty stratum containing these remains. It is important to notice this circumstance, says Professor Buckland, because it has been supposed by many persons who have never visited the quarries, that the remains are lodged either in fissures and cavities, or in a superficial and merely local deposit. This is decidedly not the case. They are absolutely imbedded in a deeply situated regular stratum of the rock itself, which is known to extend across England, from Coley-Weston near Stamford in Lincolnshire, to Hinton near Bath, and is in many places extensively quarried for coarse oolitic slate, used for covering houses. Many of these quarries abound in marine and vegetable remains; but the megalosaurus, opossum, birds, and coleopterous insects, have as yet been observed in it, only at Stonesfield.

The megalosaurus was probably an amphibious animal. To judge from a thigh bone of another of the same species, discovered in the ferruginous sandstone of Tilgate forest near Cuckfield in Sussex, which is preserved in Mr. Mantell's valuable collection, the animal must have equalled in height our greatest elephants, and in length have come but little short of the largest whales; but as the longitudinal growth of animals is not in so great a ratio as their height, after making some deductions, Dr. Buckland calculates the length of this reptile from Cuckfield at from sixty to seventy feet!

The teeth of this animal are lodged in distinct alveoli or sockets, but do not adhere as in the monitors, by any incorporation of the root or sides, with the substance of the jaw: the young teeth are hollow at the base, and, as usual become filled as they grow older. The new teeth are formed in distinct cavities by the side of the old ones, towards the interior surface of the jaw, and probably expel the old teeth by the usual process of pressure and absorption, and insinuate themselves intothe cavities thus left vacant.

Tooth of Megalosaurus.

The teeth are flattened laterally, and recurved backwards, being serrated on the posterior edge along the whole extent of their enamel, and also on the anterior edge when young. This edge is thicker, and like the back of a knife, is more solid, than the posterior or cutting edge. The figure in the margin represents a tooth of the natural size.

The late M. Collini, director of the Cabinet of the Elector Palatine was the first to describe a genus of *Saurian* reptiles, characterised by the excessive elongation of the 4th toe in front, to which animal M. Cuvier has given the name of *Pterodactyle* (wing-toed). It was found in one of the marly stones, foliated, gray, and sometimes yellowish, of Aichstedt, which abound in dendrites, and animal petrifactions.

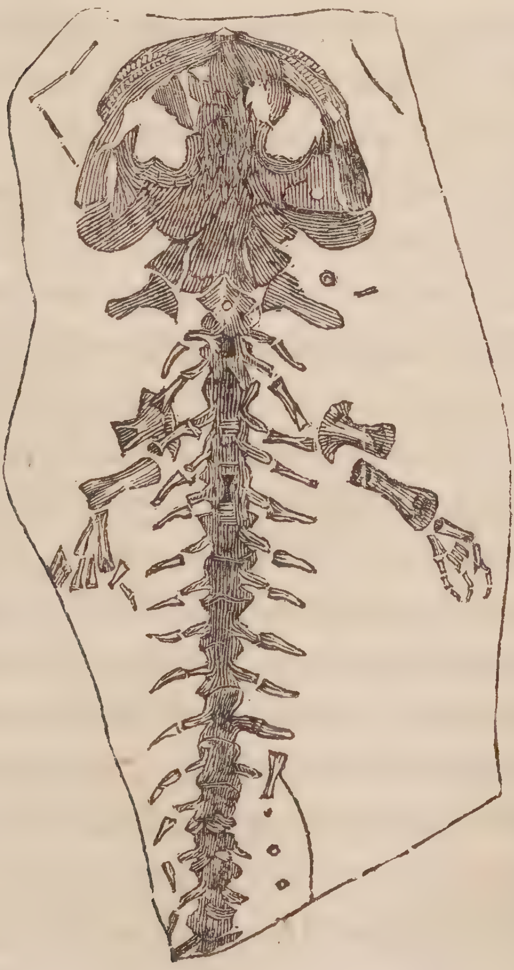
It is hardly possible to doubt, says M. Cuvier, that the long toe served to support a membrane, which furnished the animal, over the whole length of the fore leg, with a much more powerful wing, than that of the dragon (Draco Volans. Lin.), and at least equal in strength to that of the bat. This ancient animal could fly with a vigour proportional to its muscular power; and then it could make use of its three short toes, armed with crooked claws, to suspend itself from trees. We have here an animal which in its osteology, from the teeth to the extremity of its claws, presents all the classic characters of the saurians or lizards. There is no reason to doubt of its having also had their generic characters in its integuments and soft parts; of its having their scales, organs of circulation, generation, &c. But it was, at the same time, provided with the means of flying; an animal which in a standing posture could make little use of its fore-legs, if it did not keep them always folded up, as birds do their wings; which could however also employ its small fore-toes for hanging itself to branches of trees, though its posture of repose must have been usually on its hind feet, just like that of birds. It must moreover have held its neck reverted, as birds do, to prevent its enormous long head from upsetting its equilibrium.

From these *data*, it would be possible to figure it in the living state; but the picture we should form would be most extraordinary; and would appear to those who had not minutely followed out its anatomical structure, as the offspring of a distempered imagination, rather than a natural pro-

duction. Something very like it may occasionally be seen in the grotesque paintings of the Chinese.

From the same strata, in the quarries of Windischhof, half a league from Aichstedt, a small Pterodactylus with a short beak has been extracted. These are incontestably the most extraordinary of all the creatures whose ancient existence has been revealed in the bowels of the earth; creatures which were they seen alive, would seem most alien from the system of animated nature.

Animals analogous to the frog, the toad, the salamander, those naked reptiles subject to metamorphoses, which form a small family, quite insulated in the animal kingdom by their whole organization, existed at the same remote period in the



strata disordered by the revolutions of the globe, and although they were different in species, they were subject to the same laws of co-existence and form of the organs. Only a few of them have been found in the fossil state, and in few places. Possibly there are none absolutely certain besides those of the marvellous quarries of Æningen. The pretended fossil

man of these quarries, described by Scheuchzer, which other naturalists regarded as a *silurus*, is according to M. Cuvier merely an aquatic salamander of gigantic size, and unknown species. Scheuchzer gave an abridged account of this animal in the Philosophical Transactions, for 1726, and made it also the subject of a particular dissertation, entitled *Homo Diluvii Testis*, The Man who witnessed the Deluge. It must have required all the blindness of the spirit of system to make such a person as Scheuchzer, a physician who ought to have seen human skeletons, deceive himself so grossly; for this fancy of his cannot sustain the slightest examination. This fossil skeleton, as a little further chiseled out of its rock by Cuvier, is represented in our figure, p. 225. Another of a similar animal, described by John Gesner in 1758, was a *silurus glanis*. The form of the head, the immense orbital holes, the want of teeth in the jaws, with many other distinct circumstances, prove that there is nothing human about these fossil remains.

They are precisely like skeletons of the salamander species.

THE ICHTHYOSAURUS AND PLESIOSAURUS, TWO MONSTROUS SEA LIZARDS.

We are now come to those among the reptile tribe, or perhaps among all fossil animals, which bear the least resemblance to the individuals now known, and which are most calculated to surprise the naturalist by combinations of structure, almost incredible to every one who may not have observed for himself, or who entertains the slightest doubt

about their authenticity. In the first of these two genera, we see a muzzle of a dolphin, teeth of a crocodile, a head and breast of a lizard, paws of a cetaceous animal or paddles of a turtle, four in number, and finally, vertebræ of a fish; in the second, with the same turtle paddles, we have a lizard's head, and a long neck like the body of a serpent: these singularities are now exhibited to us in the Ichthyosaurus and Plesiosaurus, after being buried for so many thousand years, under an enormous mass of stones and marbles. It is to the more ancient secondary strata that they belong. None of them are found except in those beds of marly stone or grayish marble, filled with pyrites and ammonites, or in the oolites; all mineral formations of the same order as the Alpine limestone. It is in England especially that their remains appear to be abundant; and it is to the zeal of the English geologists, that our knowledge of them is due. They have spared no pains to make a large collection of their relics, and to join them together in as systematic a frame, as the state of the fragments would permit.*

Notwithstanding the anomalies of their structure, these animals approach more nearly to lizards than to any other genus, and they might therefore have been discussed at the end of the saurian tribe. But certain anomalies, and the doubts which they had at first excited, are sufficient reasons for placing their description here, in order to bring them into comparison with a greater variety of objects.

* This merited eulogium of the English geologists is from the pen of Cuvier.

OF THE ICHTHYOSAURUS.

It is to Sir Everard Home that the scientific world owes its first acquaintance with a characteristic specimen of this extraordinary genus. He published in the Phil. Trans. for 1814, the description of a very well preserved head, and some other bones deposited in Bullock's Egyptian Museum, Pall-Mall. They came from the coast of Dorsetshire between Lyme and Charmouth; and had been extracted from a rock thirty or forty feet above the level of the sea.

The author soon perceived that the shoulder bone exhibited some relations to that of the crocodile; but the position of the nostrils, the circle of bony pieces, which surrounds the sclerotic coat of the eye, appeared to him, as well as the vertebræ, akin to those of fishes; on which considerations M. Kœnig, of the British Museum, invented the name Ichthyosaurus (fish-lizard).

Two years thereafter (in the Transactions for 1816) Sir Everard added several details to his first notices. Mr. Johnston of Bristol, who was for many years occupied in collecting fossils from the cliffs of Lyme, supplied some fragments, through which Sir Everard was enabled to determine the articulation of the ribs, the shoulder-blade, and the whole of the fore paddle, which he then compared to the

fin of a shark; whence he concluded with greater probability that it was a fish.

But after other two years (in 1818) pieces collected by other individuals, to which Professor Buckland directed his attention, made Sir Everard acquainted with the sternum, the clavicles, and the coracoid bone, as well as the relations of these parts with their fellows in the ornithorynchus, which resemble those of the lizard tribe. Sir E. then abandoned the idea that it could be a fish. In the same Memoir he announced the probable existence of more than one species of this genus.

In 1819, very fine fragments, and also an entire skeleton, discovered by Mr. Labeche and Colonel Birch of Lyme, enabled Sir Everard to improve his description still further, and to satisfy himself completely that the ichthyosaurus had four feet. But a head with the nostrils filled up, misled him into the belief that what he had hitherto taken for these apertures was the effect of accident alone. In the Philos. Trans. of this year the author further proposed for his animal the term *proteosaurus*, from the resemblance of the concave faces of the fossil vertebræ with those of the proteus, the siren, and the axolotl.

Lastly, in 1820, the indefatigable researches of Colonel Birch furnished Sir Everard with further materials from which he determined the composition of the vertebræ, and the manner in which the annular part was articulated with the body, as well as the singular structure of the fins.

This excellent series of Memoirs and Notices

secures to the English Baronet the sole honour of revealing to naturalists the extraordinary genus under consideration. Messrs. Conybeare and La-beche have, however, added several interesting particulars, and extensive details, to those of the learned anatomist.

In a memoir inserted in the Geological Transactions for 1821, these two gentlemen published their great discovery of a new genus of the same tribe, but more akin to the ordinary saurians, which they called *plesiosaurus*. They also described the composition of the lower jaw of the ichthyosaurus, that of the muzzle, and a great portion of the posterior and inferior faces of the cranium. They showed that the ring of bony pieces at the sclerotic is characteristic of a lizard, but not of a fish, and entered into new details on the vertebræ and articulation of the ribs.

A *second Memoir* of the same authors, in the Geological Transactions for 1823, at the same time that it extended the description of the *plesiosaurus*, fixed more clearly our ideas about the teeth of the *ichthyosaurus*, expressed distinctly the characters of its species, re-established the truth with regard to the position of its nostrils, and marked the relations and the differences of structure between its head and that of lizards.

It was now possible, with materials so copious, and presented with so much care by the authors of these Memoirs, to compose an osteological description of the ichthyosaurus, as complete at least as that of any other extinct animal. M. Cuvier could

have joined to these, several drawings and fragments which had been sent him by the friends of science. It remained for him to show the form of the frontal bone and its accessories, the hole of the parietal similar to that of lizards, and the sphenoid also much liker that of lizards, than it had appeared in the remains previously analysed. The ichthyosaurus is peculiarly abundant in England. Its remains are deposited from the new red sandstone up to the green sand, immediately below the chalk; hence it belongs to almost every epocha of the secondary formations. Fragments of it are in fact found in a marl associated with green sand, at Bensington; in the calcareous sandstone under the oolite at Marcham; immediately under the oolite, at Shotoverhill; all places in the county of Oxford. There are also some specimens under the oolite at Kimmeridge in Dorsetshire.

But it is especially the lias of the English geologists, that bluish-gray, marly, and pyritous marble, which seems to have been its sepulchre. This has furnished innumerable remains of it in the counties of Dorset, Somerset, Gloucester, and Leicester; and principally in the valley of the Avon, in the county of Somerset between Bath and Bristol, and on the Dorsetshire coast, where the cliffs between Lyme and Charmouth appear to be inexhaustible quarries of ichthyosaurus. It is there found nearly as the palæotheriums are in the plaster beds of Montmartre; their bones being surrounded with a quantity of small ammonites.

Portions of it are also found in the same stone-

bed, much further to the north, for great fragments have been obtained from Newcastle in Northumberland.

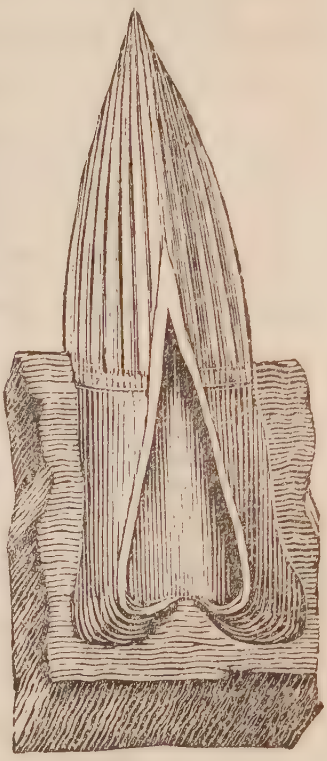
The ichthyosaurus bones are much rarer on the continent; only among the groups of crocodile bones from Honfleur, some of its vertebræ may be recognised. A few others have been detected in France and Germany, especially from the neighbourhood of Altorf, which were foolishly mistaken at one time for human vertebræ. Very lately there have been discovered a skeleton almost entire, and several other relics of ichthyosaurus at Boll in Wirtemberg, the same place where fossil crocodiles and other organic remains were found in great number, among the secondary formations. They lie in a calcareous schistus analogous to that of Solenhoffen.

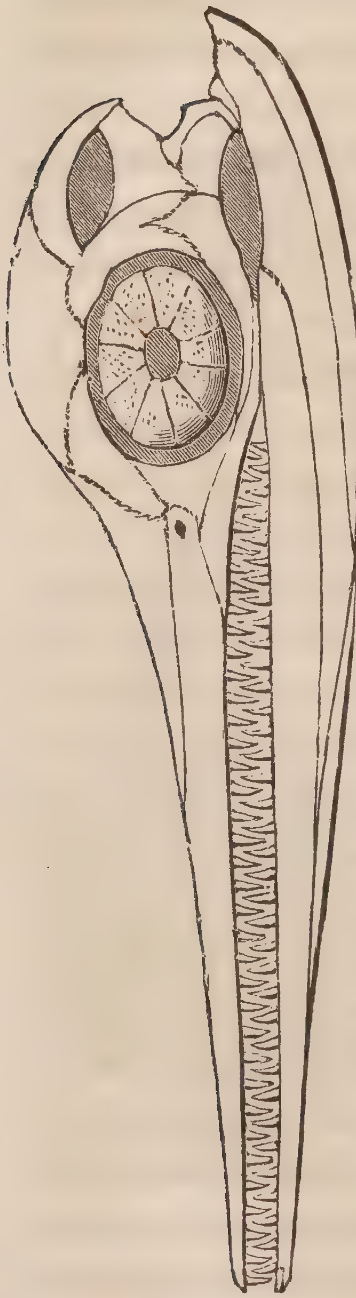
The teeth of ichthyosauri are conical, and their corona (summit) is enamelled, and longitudinally striated as in the crocodiles.

The number of teeth is considerable. Mr. Conybeare counts no less than 30 on each side of each jaw; and Sir E. Home shows 45 in the individual of his xv. Plate, Phil. Trans. 1820. Messrs. Labeche and Conybeare have found sufficient differences among these teeth to deduce from them the characters of four distinct species.

The teeth of the ichthyosaurus are lodged loosely in a long continuous furrow, retained only as it would appear, by the substance of the gum. This structure is widely different from that of the monitors, and ordinary lacertæ, where the teeth adhere to the jaw by a solid bony union. It differs much

less from that of the crocodile; the only variation being that the alveoli (which in the crocodile are separate) here run together into one long continuous furrow; in which, indeed the rudiments of a separation into distinct alveoli may be traced, in the slight ridges extending between the teeth along the sides and bottom of the furrow. The appearance and progress of the new tooth, which is to replace the old one, is very nearly the same in the ichthyosaurus and crocodile. In the latter animal they always remain hollow. The new tooth first appears as a germ within the root of the old one, whence by elongation, it rises up into its cavity, and by its increase splits the old tooth, whose fragments soon fall off. In man and most mammalia there is only a single change of teeth; but in the crocodile, there is a continual succession of fresh teeth, the interior is never filled up with bony matter, and the process may be traced in all its stages in the jaws of crocodiles of every age. In the ichthyosaurus, however, the interior cavity of the teeth is gradually obliterated in old age, by the ossification of the pulpy nucleus. In this animal, therefore, the succession of new sets of teeth is but seldom repeated, and perhaps not more than once. This curious teething process is represented in the figure of the natural size on the margin.





Osteology of the head of the Ichthyosaurus. The eye is placed rather lower than in the crocodiles.

What is most striking in the head is the enormous size of the eye, and the circle of bony pieces which strengthen the sclerotic in front. These pieces form, as is known, a character common to birds, tortoises, and lizards, to the exclusion of crocodiles and fishes. In fact, the sclerotic of the crocodile is simply cartilaginous; in fishes, it is often osseous in whole or in part, but in them it is never furnished in front with a ring of bony pieces as in birds. This marked character, which had at first, nobody knows why, caused this animal to be likened unto fishes, ought rather to have associated it with lizards.

The number of the vertebræ is very considerable. Mr. Conybeare reckons between 80 and 90 of them: M. Cuvier possesses an individual that must have had 95. Those distinguishable in the fine skeleton of Sir Everard Home, amount to 72 at least. As much as the ichthyosaurus resembles lizards by the osteology of its head, so much does it differ in the forms of its vertebræ; and in this respect it approaches at once to fishes and cetacea, as Sir Everard had very justly remarked.

The ribs are very slender for so great an animal, and are not compressed, but rather triangular. The shoulder and the breast bone of the ichthyosaurus are disposed essentially as in the lizards. The fin is formed by a series of small bones, comparable to the phalanges of the dolphin, but still more numerous and condensed. All these bones, upwards of 100 in one paddle, are flat, and their angles are tesselated like a pavement, having little motion on each other, and exhibiting no external division in the living animal.

Thus we possess the skeleton of the ichthyosaurus in all its parts, and excepting the form of its scales and the shades of its colours, nothing hinders us from making a complete representation of this animal.

It was a reptile with a moderate tail, and a long pointed muzzle armed with sharp pointed teeth. Two eyes of enormous magnitude must have given its head a most extraordinary aspect, and have facilitated its vision during the night. There was probably no external ear, and the skin passed over the drum bone, as in the cameleon, the salamander, or the pipa, without even becoming any thinner. It naturally breathed air, and not water like fishes; hence it was often obliged to come to the surface. Nevertheless its short, flat, undivided limbs allowed it merely to swim, and it is very probable that it could not even crawl on the shore as well as the seals do; but that if it had the misfortune to be wrecked there, it would remain motionless like whales and dolphins. It lived in a sea inhabited at the same time by mollusca, which have left

ammonites, animals to all appearance, forming species of sepia or pulps, which contained in their interior (as at the present day the *nautilus spirula*) those spiral and singularly chambered shells. Terebratula with different species of oysters abounded also in this sea, *and several sorts of crocodiles frequented its shores; if even they did not inhabit it conjointly with the ichthyosauri.**

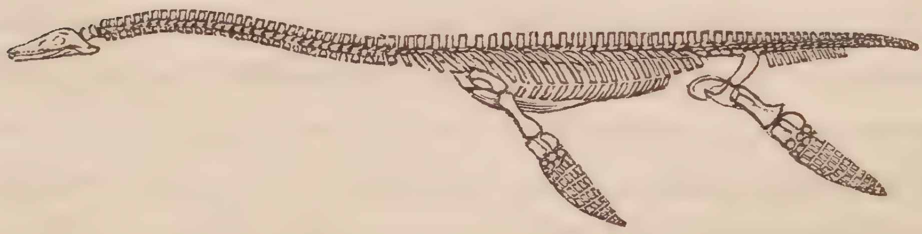
We can assign with precision, at least in the species with a slender muzzle (*I. tenuirostris*) the proportions of its parts. In a total length of three feet and a half, which is that of M. Cuvier's little skeleton, the head and tail take up each one foot, and there remains a foot and a half for the trunk, at the two extremities of which are the fins; for one can scarcely say that there has been a neck. The fore fin (counting the humerus or shoulder bone) was seven inches and a half long, with a breadth of nearly three inches. The posterior fin was a little less both in length and breadth.

The great head of the *I. Communis*, possessed by M. Cuvier, must have had a length of at least 2 feet and a half; hence it indicates an individual about 9 feet long. A skeleton discovered on the coast of Dorsetshire by Miss Mary Anning has however been referred to this species, although it is only 5 feet long. In reality, among reptiles, the size may vary from double to single, without the teeth denoting the age. But there are much greater ichthyosauri, particularly in the species—*platyodon* (broad toothed). Miss Anning, it is said, has also discov-

* Cuvier. Ossemens Fossiles, Tom. V. Part II. p. 473.

ered a skeleton 20 feet long. Mr. Johnson possesses a cranium whose breadth behind is two feet six inches, and the longitudinal diameter fourteen inches; and M. Cuvier has vertebræ 6 inches in diameter, which compared to those of his little skeleton whose diameter is only one inch, may have belonged to individuals of twenty-one feet. Cuvier received from Dr. Davis of Bath, a drawing of one of these vertebræ found in oolite near that city, which is nearly 7 inches long. And he has himself fragments of fins from Newcastle which correspond to individuals of a very great size. This species of ichthyosaurus did not come far short of the *mosasaurus* of Maestricht, whose length has been calculated at 25 feet.

OF THE PLESIOSAURUS.



This genus is also entirely English, and solely due to the sagacity of Mr. Conybeare. Some vertebræ mixed with those of the crocodile and ichthyosaurus, in the lias of the environs of Bristol, appeared to him to differ from those of both animals. A considerable portion of a skeleton in the collection of Colonel Birch, confirmed him in his ideas about the species from which these relics came. In order to complete his arrangement, he added some bones of the extremities found along with these vertebræ, and thus he was enabled to

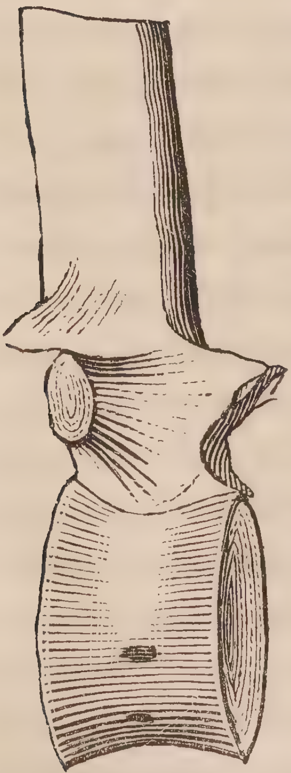
publish the characters of the new animal in 1821, in a memoir conjointly with Mr. Labeche, inserted in the fifth volume of the Geological Transactions. The head meanwhile was wanting; but having continued his researches in concert with Mr. Labeche, and profiting always by the acquisitions of Colonel Birch, in the following year Mr. Conybeare found himself qualified to describe a tolerably entire head, though slightly crushed, and a large under jaw bone which he was inclined to refer to that species. To this he annexed figures of several bones (Geol. Trans. Vol. I. second series). In the same year (1824) in the month of January, an almost entire skeleton found at Lyme Regis, came forward to confirm or rectify his conjectures on the parts he had previously examined. But he now learned an entirely new peculiarity, which could not have been anticipated,—that the neck of this animal was of a most disproportionate length, and composed of many more vertebræ than are seen in the longest necked birds, even in the swan, which surpasses in this respect every other animal. This astonishing relic was purchased by the Duke of Buckingham, and placed at the disposal of the Geological Society. This inhabitant of the ancient world appears the most heteroclite, or equivocal; —the one above all others deserving the name of monster. The name *Plesiosaurus*, assigned by Mr. Conybeare, signifies akin to lizards, because he conceived it to be liker the animals of this genus than the ichthyosaurus.

In consequence of these memoirs of Mr. Conybeare, M. Cuvier examined anew several vertebræ

and some other bones from Honfleur, to which he had previously directed his attention, and he was convinced that they were relics of the plesiosaurus. Hence it is not to be doubted that this animal is found also in the beds on the French side of the Channel, and that it is there accompanied as in England by the ichthyosaurus and crocodiles of different kinds. He has also procured some from the interior of France, from the neighbourhood of Auxonne, department of the Cote d'Or. Several likewise exist in England at a distance from Lyme, for M. Brogniart obtained fragments at Newcastle on the Tyne.

The superb relic of Lyme is composed of several blocks which fit well to one another. The animal is lying on its belly, and its length, in the state in which we see it, is 9 feet 6 inches, from the tip of the muzzle to the end of the tail. The head is a little advanced before the rest with six vertebræ attached to it in a continuous series; next come four vertebræ a little displaced; but the series is again resumed, and presents 18 vertebræ in their natural order. After this, 12 are seen more or less deranged, some of which may possibly belong to the back. The six following are nearly in their places, concealing the humero-sternal apparatus under them; next are two crosswise, and afterwards three thrown considerably from their natural position. The remainder of the vertebræ of the back, to the basin (pelvis), eleven in number, are well arranged in the series, but altogether out of the direction of the spine, and thrown to the left side, permitting the arrangement of the abdominal ribs to be seen.

The basin, also, is in a great measure exposed to view. Behind the basin, twenty-five vertebræ may be counted forming the tail, all nearly in a line, except the sixth and the seventh, and still furnished in a great measure with their little bones *en chevron.* There are pretty entire relics of the four limbs ; the anterior one of the right side, and the posterior of the left side, are as complete as could be desired for description. Those vertebræ which originally led to the recognition of the plesiosaurus, are easily distinguished by two small oval fossets (dimples) which they all have at their lower face, and by the surface of their body slightly, if at all concave, while the middle part is even a little convex.



Vertebra of the Plesiosaurus, agreeing more nearly with the crocodile than the ichthyosaurus. It is concave at both extremities of its body.

The forms of the vertebræ of the plesiosaurus, however peculiar they may be, and notwithstanding the length of their axis, unquestionably resemble those of crocodiles, and especially certain fossil crocodiles, such as that of Caen and the second of Honfleur, much more than they do those of the ichthyosaurus, or even lizards. Mr. Conybeare was therefore right in considering the plesiosaurus as approaching in several respects to crocodiles, at the same time, that by its limbs it was nearly akin to the ichthyosaurus.

As to the number of vertebræ, Mr. Conybeare had calculated from his first researches, that there

might be in the neck and back altogether 46, which far exceeds that of all the saurians known; even the ichthyosaurus. The skeleton of Lyme, however, exhibits obviously in their place, thirty-five cervical vertebræ, bearing only little ribs jointed by two tubercles, and terminated in the form of a hatchet, somewhat like the small ribs of the crocodile; then appear six whose little ribs are elongated, assuming by degrees the form of dorsal ribs. The vertebræ of the back and the loins are somewhat in disorder, so that one cannot say precisely whether their number be complete. Twenty-one have been counted. There are afterwards twenty-three caudal vertebræ (of the tail), and three seem wanting at the end, which would raise their number to twenty-six. Thus, there are 88 vertebræ, to which Mr. Conybeare adds two sacral vertebræ, making 90 in whole. At the beginning of this series of vertebræ, there is in the skeleton a head so small, that taking it for unity, the neck has five times its length, the trunk four times, and the tail three. Hence the head would constitute only a thirteenth of the whole length.

It is therefore quite certain that the plesiosaurus in the living state must have presented a true serpent neck, borne on a trunk whose proportions differed little from those of an ordinary quadruped. The tail especially by its shortness, could scarcely remind one of a reptile, and hence this animal must have displayed a form so much the more singular, as its extremities like those of the ichthyosaurus, were genuine fins similar to those of cetaceous fishes.

The head of this animal is the part least understood, but still it is evidently a lizard's head, with some characters of the crocodile and the ichthyosaurus. It appears that in these two extinct genera of reptiles, as in the cetacea, the nostrils were not near the tip of the muzzle, but immediately below the anterior edge of the orbit, where a small hole and a groove leading to it may be perceived. The teeth of the plesiosaurus are slender, pointed, a little curved, and *longitudinally channelled.* They are unequal. Twenty-seven sockets are to be observed on each side of the lower jaw. Teeth have been found much larger than those which belong to the Lyme skeleton; M. Cuvier refers these to an animal at least 30 feet long.

Of the plesiosaurus, as of the ichthyosaurus, there are several species. That of Lyme has been called by Mr. Conybeare *Pl. Dolichodeirus* or long-necked; and that whose vertebræ come from Kimmeridge, *Pl. recentior* (more modern). But other species seem to exist.

From the splendid specimen of bones found at Lyme, we have seen that the head of the plesiosaurus was remarkably small, forming less than the thirteenth part of the total length of the skeleton: whereas in the ichthyosaurus, it is one-fourth. This smallness of head and teeth, must have rendered it hardly a match for the ichthyosaurus; unless the long flexible neck made a compensation in activity, for defect of force. In its motion, this animal must have resembled the turtle more than any other; as also somewhat in figure, were the turtle divested of its shelly case. That it was aquatic is evident from

the form of its paddles; that its element was the sea, may be equally inferred from the remains with which it is universally associated; and that it may have occasionally visited the shore, the resemblance of its extremities to those of the turtle may lead us to conjecture. Its motion on land, however, must have been very awkward. Its long neck would impede its progress through water; presenting a striking contrast to the swimming organization, which fitted the ichthyosaurus to cleave the waves. May it not therefore be concluded, says the Rev. Mr. Conybeare, since its respiration required frequent access of air, that it swam upon or near the surface, arching back its long neck like the swan, and occasionally darting it down at the fish which happened to float within its reach? It may perhaps have lurked in shoal water along the coast, concealed among the sea-weed, and raising its nostrils, like the alligator, to a level with the surface, may have found a secure retreat from the assaults of powerful land enemies. By the suddenness and agility of its attack, it might easily make a prey of all the feebler animals which came within the sweep of its neck.

In the first part of the Philosophical Transactions for 1825, there is a most interesting communication by Gideon Mantell, Esq. on the teeth and bones of a fossil herbivorous reptile found in the sandstone of Tilgate forest, a part of the iron-sand formation, which forms in Sussex a chain of hills that stretches through the county in a W.N.W. direction, from Hastings to Horsham; whence it has been recently called the Hastings-sand formation. In various

parts of its course, but more particularly in the country around Tilgate and St. Leonard's forests, the sandstone contains the remains of saurian animals, turtles, birds, fishes, shells, and vegetables. Of the saurians, three if not four species belonging to as many genera are known to occur; viz. the crocodile, megalosaurus, plesiosaurus, and the *iguanodon*, the animal whose teeth form the subject of Mr. Mantell's paper.

The teeth of the crocodile, megalosaurus, and plesiosaurus, differ so materially from each other, and from those of the other lacertæ, as to be identified without difficulty; but in the summer of 1822, others were discovered in the same strata, which although evidently referable to some herbivorous reptile, possessed characters so remarkable, that the most superficial observer would have been struck with their appearance, as indicating something novel and interesting.

Mr. Mantell compared these singular teeth with those of the recent lacertæ in the Museum of the Royal College of Surgeons. The result of this examination proved highly satisfactory, for in an iguana, teeth were discovered possessing the form and structure of the fossil specimens. The tooth figured in the margin represents the outer surface of one of the largest and most perfect specimens of the teeth of the *iguanodon*. Here we see, the surface

of the tooth worn down obliquely by mastica-

tion; its serrated edges; the fang broken, and the hollow filled with sandstone; and the cavity or depression in the base of the fang, the effect of absorption caused by the pressure of a secondary tooth. The figure is of full size.

Like the teeth of the recent iguana, the crown of this tooth is acuminated; the edges are strongly serrated or dentated; the outer surface is ridged, and the inner smooth and convex. The teeth appear to have been hollow in the young animals, and to have become solid in the adult.

If any inference may be drawn from the nature of the fossils, with which the remains of the iguanodon are associated, we may conclude that if amphibious, it was not of marine origin, but inhabited rivers or fresh-water lakes. If the fossil and recent animal bore the same relative magnitudes, as their teeth, the one figured above must have belonged to an individual upwards of 60 feet long; a conclusion concerning the iguanodon in perfect accordance with that deduced by Professor Buckland from a femur (thigh bone) and other bones in Mr. Mantell's possession. Some further remarks on this great reptile will be found in Book III. Chap. iii. section 2.

From Mr. Mantell's researches there is every reason to believe that the iguanodon had a very remarkable appendage to its head, a horn, equal in size to the lesser horn of the rhinoceros, and not very different in form. The relic which he found of this appendage, is externally of a dark brown colour; some parts of the surface being smooth, while others are rough and furrowed, as if by the

passage of blood vessels. It possesses an osseous structure without internal cavity; but does not seem to have been united to the skull by a bony union, as the horns of the mammalia are. Among living *iguanas*, the horned species are most abundant. The *iguana cornuta*, a native of St. Domingo, resembles the common iguana in size, colour, and general proportions. On the front of the head, between the eyes and nostrils, are seated four rather large, scaly tubercles; behind which rises an osseous conical horn or process covered by a single scale. That the fossil horn of Mr. Mantell was such an appendage, there can be no doubt. Its surface bears marks of the impression of an integument by which it was covered, and probably attached to the skull.—*See Mantell's Geology of Sussex.*

We cannot help admitting for the future, among our best established truths, that vast multitudes of reptiles of marvellous magnitude and variety inhabited the seas, or covered the surface of the globe at the ancient epoch, in which were deposited the strata commonly denoted in France by the too indefinite term of Jura formation; living in a wide waste of waters and marshes, where they died and were buried aloof from mammiferous animals. Time will possibly complete our knowledge of many beings, whose ancient existence is inferred from a few bony relics; and from the ardour with which these researches are now cultivated on every side, that time is probably not far distant. "I doubt not," says M. Cuvier, "that in proportion as the discoveries already made become more perfect, new discoveries will be multiplied, and in a few years

perhaps, I may have to acknowledge that the work just now finished, to which I have devoted so much labour, may appear but a superficial sketch, an opening glimpse, of the immense creations of the primeval world."* This modest conclusion of the illustrious naturalist of France is almost the only one of his, from which the learned world will withhold their assent. In zoological and anatomical knowledge, in acuteness of discrimination, sagacity of comparison, soundness of inference, and above all, in general enlargement of thought, his talents and genius have secured to the *Ossemens Fossiles*, a noble and enduring station among the trophies of science.

§ V. INFERIOR MEMBERS OF THE THIRD OR LOWER SYSTEM OF OOLITES.

The neighbourhood of Bath affords the best type of the arrangement of this part of the mineral series. In this district the separate beds appear most strongly characterised, and most distinctly divided. We shall study them, as usual, in their ascending order; beginning with the lowest.

The following section of Down Cliff between Seaton and Thorncombe two miles west of Bridport harbour, will give an idea of this bed, from above downwards.

	Feet.
1. Inferior oolite and sand alternating, the sand at the surface passing into marl, about . . .	80
2. Sandy marl, ...	50
3. Rusty sand with ferro-argillaceous concretions, whose cavities are filled with sand, ...	50
4. Greenish-blue micaceous sandy marl, containing indurated concretions of similar constitution, .	80

* Cuvier—Ossemens Fossiles. Tome V. Partie II. p. 487.

This stratum passes into the lias marl of the inferior strata. Immediately on the east of Burton cliff (about 3 miles east of Bridport harbour), the fuller's earth may be seen resting on the preceding beds.

This lower system of oolites is generally covered by a thick bed or series of beds of calcareo-argillaceous formation. These usually carry one or more indurated rocky strata, besides frequent courses of a soft rubbly stone, in which the calcareous matter predominates. Here is found the fuller's earth, sometimes, as in the neighbourhood of Bath, in seams 8 feet thick. The inferior oolite is distinguishable from the great oolite by the larger proportion of brown oxide of iron disseminated through its mass. This sometimes occurs in minute globular particles, occupying the same situation with the egg-shaped particles of the superior oolite. The iron gives a brownish tinge, passing into blue or gray. The texture is mostly too coarse for any other purpose than making roads; being rarely fine enough for architectural uses. It may be well distinguished by its fossils.

In the midland counties, calcareous matter is less abundant in these beds. A ferruginous sand or sandstone, containing a very small proportion of lime, predominates. In Oxfordshire the series below the fuller's earth, appears to be; 1. Sand and sandstone with a slight calcareous mixture, highly ferruginous, and frequently so micaceous, as to exhibit large scales of mica. Few fossils, except some belemnites, occur; but towards the bottom, white pearly shells of numerous plicated terebratulæ, are scattered through the dark ground.

Ammonites, belemnites, and gigantic limas are also to be seen. The whole of this sandstone series is generally separated from the great oolite by a thick clay, equivalent to that of the fuller's earth.

2. Marl and marl sandstone corresponding to No. 4 of the Down cliff section, given above. This marl is sandy, gritty, micaceous, and of a green colour, from a copious admixture of slightly oxidised iron. Its calcareo-siliceous grit contains casts of several shells, but their substance is commonly gone. The terebratulæ of the lower beds are wanting. These beds are occasionally quarried for flagstones or cisterns.

Thus the lowest beds of this series consist generally of a green sandy marl, containing similar concretions and rock masses. They form a gradual transition into the lias marls.

The *organic remains* of vertebral animals are very rare in all these beds. Fragments of the claws of marine *crustacea* occur in the inferior oolite at Dundry, and in the marly sandstone in the north of Oxfordshire. In the inferior oolite, among the *testaceous* remains, are abundant casts of ribbed and studded Trigoniæ; immediately over which is a hard and compact coral bed, containing large specimens of *Madrepora cinerescens.* In the superior bed, the fossils are very numerous indeed.

CHAMBERED UNIVALVES.

Fuller's earth.	*Inferior oolite.*	*Marly sandstone.*
Ammonites.	A. discus and other 18 species.	A. 3 species.
Modiolaris.		
Nautilites.	N. 3 species.	Nautilus.

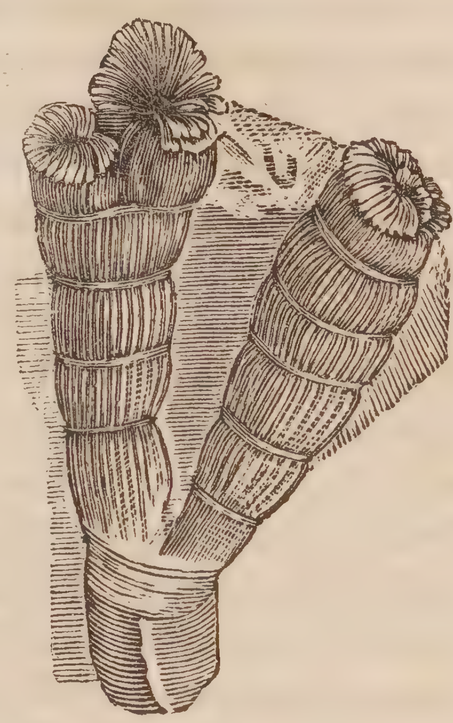
Belemnites.	B. various forms.	Belemnites, various.
Trochus (casts).	T. about 20 species.	T. ?
	Serpula triquetra.	

EQUIVALVED BIVALVES.

Fuller's earth.	*Inferior oolite.*	*Marly Sandstone.*
Trigonia clavellata.	Trigonia 4 sp.	
	Cucullœa.	
Cardium 2 sp.	Nucula.	Cardita 2 sp.
	Cardita 4 sp.	
Lutraria gibbosa.	Lutraria 3 sp.	Lutrar. gibb.
	Astarte 4 sp.	
Unio.	Unio Listeri.	Unio.
	Mya 2 sp.	
	Fistulana ampullaria.	
	Mytilus.	
Modiola anatina.	Modiola plicata.	M. Cun.
	M. Cuneata.	
	Donax.	
	Pinna.	
Terebratula (not plicated).	Terebratula (not plicated).	Terebratula (not plicated).
2 varieties.	7 varieties.	3 varieties.
	Terebrat. plicat.	
Ter. plic. 3 var.	3 varieties.	T. p. 3 var.
Ostrea 3 sp.	Ostrea 5 sp.	Ostr. several.
Pecten 1 sp.	Pecten 4 sp.	Pect. several.
	Lima 2 sp.	Lima 1.
	Avicula 1 sp.	
	Perna 1 sp.	
Plagiostoma ovalis.	Plagiostoma punctata and 2 other sp.	

(*See Plate* iii.)

In these beds, several species of Echinus occur; and of the Encrinital family, the Pentacrinites caput medus, and Pentacrinites of Miller are found. Among the coralloid order, we have several species of the Astrea, a Caryophyllia, a Fungia, a Cyclolites, and a Cellepora. Traces of Alcyonia may also be observed.



Caryophyllia.

The range and extent of these beds are very considerable, as they stretch diagonally across the island from north-east to south-west. They constitute the sandy district of the eastern moorlands in Yorkshire. Their ferruginous freestones are displayed on the borders of Lincolnshire and Leicestershire, in the hills above Grantham and the vale of Belvoir. They occupy all the western half of Rutland. For most ample and satisfactory details, see *Conybeare's and Phillip's Geology of England, 245 et seq.*

This formation occupies considerable heights. Roseberry Topping is 1022 feet high, Arbury hill 804, Epwell hill Oxfordshire 836, Dundry hill Somersetshire 700; all consisting of the inferior oolites.

The average thickness of these beds is about 400 feet. The inclination of the strata is conformable

to the secondary formations of these districts, dipping to the south-east under an almost inappreciable angle. The faults of the subjacent strata, have, in general, not affected this, showing it to be of posterior formation; but near the village of Paulton, in Somersetshire, a fault which traverses the subjacent colliery has thrown down the stratum of the inferior oolite 20 fathoms to the north, bringing it to the level of the lias. (See the figure under Coal-measures, p. 159.) Similar cases occur, where the inferior oolite sands are thus made to abut abruptly against the lias and subjacent new red sandstone. In the immediate vicinity of Bath, there are numerous instances of dislocations of the strata. Not merely the bastard free-stone, but all the strata being disrupted to a great extent, have fallen down towards the subjacent vallies, and after reiterated fractures forming steps, have sent down enormous blocks which are either piled up in heaps, or scattered on the declivities.

The sands below the inferior oolite afford very fertile soils. The red district of Oxfordshire has been considered as the glory of the county, by the author of its agricultural report.

The upper member of this series (the fuller's earth clay) throws out the waters copiously, which have percolated through the great oolite. Those of the inferior oolites and sands are thrown out by the subjacent marls. Hence this series affords two lines of springs, one near its superior, and one near its inferior plane.

§ VI. UPPER BEDS OF THE LOWER OOLITE,

Containing the subdivisions, Cornbrash, Stonesfield slate, Forest marble, and Great oolite.

The chain of hills constituting this oolitic system, when viewed generally, will be found to consist of one great oolitic mass, resting upon the beds of calcareo-siliceous sand, already described. The upper part of this great oolitic mass, however, presents strata of a character sufficiently distinct from the main body of the *oolite* to entitle them to a separate consideration. Instead of rising in thick masses, they are generally either fissile or rubbly; are much mingled with clay, forming as it were a link between the principal deposit of purely oolitic beds, and the succeeding argillaceous beds. Instead of the yellowish tinge of the oolite, they have very generally a blue colour, or in some beds a pasty appearance, and a dull chalky white. A general notion of the stratification of this district will be obtained from the following section, as taken downwards in the neighbourhood of Bath, at Tellisford and Farley Castle.

	Feet.
1. Lower part of the Oxford or clunch clay full of selenite.	
2. Cornbrash	8 to 16
3. Clay	8 to 14
4. Calcareo-siliceous sand and gritstone	10
But sometimes swelling to	40
5. Forest marble	18
6. Sand beneath the Forest marble	2
But sometimes acquiring great thickness.	
7. Clay	from 40 to 60
Sometimes thinning to	20
8. Great oolite	130

No. 1, is the bottom of the superior clay beds, to be hereafter examined.

No. 2, the Cornbrash, is a loose rubbly limestone, of a gray or bluish colour, especially near the superincumbent clay; but brown and earthy on the outside. The upper beds of the third oolitic system of Oxfordshire, which are with probability referred to this rock, are often of a chalky appearance. In Wiltshire it is called cornbrash, or corngrit; the latter is an improper name, because it is not a grit, but rubbly in that locality. At Malmesbury it becomes thick and solid, and is extensively quarried for building.

No. 3, The clay beneath is generally white near its junction with the cornbrash, and afterwards blue.

Nos. 4, 5, and 6, are intimately associated, forming an assemblage of beds of limestone generally fissile, and divided by argillaceous partings, lying between two strata of calcareo-siliceous sand and gritstone. These sandy strata usually contain about one-third of calcareous matter. The gritstone in them is hard enough to scratch glass, and forms irregular slate-like concretions. The limestone interposed between these sands is known by the name of Forest marble. Its layers are in general thin and slaty; but occasionally thickening to 2 or 3 feet. The colour of the stone is usually gray or bluish within, brownish on the outside, apparently composed of a congeries of dark coloured shells, interspersed with white oolitic particles. Bivalve shells are most common in the thick beds, and univalve in the thin. The stone is coarse-grained, but fissile, affording coarse roofing slates and flagstones. The more solid beds take a polish, and form a coarse variegated marble; whence, and from its occurrence in Whichwood forest, Oxfordshire, it has derived its name of Forest marble.

The partings of clay between the beds of this rock vary in thickness, from less than an inch to upwards of a foot. There is little doubt that the calcareous slate of Stonesfield near Woodstock, Oxfordshire, so famous for the astonishing variety of its organic remains, among which the exuviæ of birds, land animals, and amphibia, are seen mingled with vegetables and sea-shells, belongs to the same stage of the series of superposition with the *Forest marble.* The assemblage of beds worked here, consists of two fissile beds of a buff coloured or oolitic limestone, each about 2 feet thick, separated by a bed of loose calcareo-siliceous sandstone of similar thickness.

No. 7, *Clay over the oolite, or Bradford clay,* is a blue marly clay, which, at the point of its contact with the great oolite, is stuffed full of the singular organic congeries to be presently described. It is sometimes absent, and it is then impossible to discriminate between the upper beds of the great oolite, and the Forest marble.

No. 8. *Great oolite.* This, both in thickness and utility, is by far the most important of the British

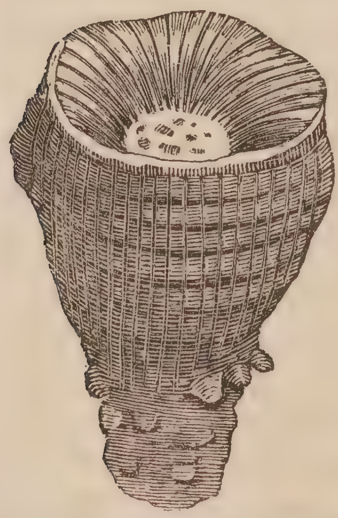
oolites. It consists of a stratified calcareous mass, varying in thickness from 130 to more than 200 feet; softer and harder beds alternate in this stratiform mass, the former exhibiting those distinct oviform concretions which give name and character to this class of rocks; the latter possessing fewer of them. The soft beds constitute an excellent freestone. The Kettering freestone of Northamptonshire, for example, is rendered extremely beautiful by the distinctness of its oolitic structure; that of Bath has generally a finer grain, and it has accordingly been employed in the late repairs of Henry the Seventh's Chapel at Westminster. St. Paul's cathedral was built principally from the quarries about a mile north of Burford in Oxfordshire. Fragments of comminuted shells may be observed in all the varieties, mingled with the oval particles, but so completely broken down that it is generally impossible to ascertain their species; hence arises our imperfect knowledge of the fossils of this formation. The colour of the freestone beds is generally white with a light cast of yellow. Of the other beds, some are gray in the middle, and some almost blue. Occasionally strata of a brown ferruginous tinge are interposed, especially at the bottom of the series near its junction with the fuller's earth. The upper beds, in which the shells become more distinct, afford indifferent freestones, and cannot be easily distinguished from the forest marble. Many beds exhibit a laminated cleavage, not parallel to the greater lines of stratification, for which they have sometimes been mistaken; and have thus given rise to accounts of highly inclined beds alter-

nating with horizontal ones in this rock. Many such appearances may be seen in the quarries near Badmington Park, the duke of Beaufort's seat in Gloucestershire. The limestone of these beds is a tolerably pure calcareous carbonate.

The *mineral* contents of this oolite are exceedingly few.

Organic Remains.—If these, like the other secondary rocks, be barren in mineralogy, they are rich and varied in zoological and vegetable fossils. These occur chiefly in the upper beds; the great central mass of oolite affording but few complete specimens, though full of comminuted fragments.

The Cornbrash, though a thin rock, has not its organic treasures equally or promiscuously distributed; since the upper beds of stone, composing the rock, exhibit fossils materially different from those of the under beds. The cluster of small oyster shells and the stems of the pentacrinus lie near together, and but few others are found near the bottom of the rock. Here also are found various Madrepores, of which one is figured on the margin.



Turbinolia, formerly Madrepora turbinata—The Top-shaped Madreporite.

In the forest marble, loose and entire specimens are rare, and separable with difficulty, though its various beds are composed of little else than a mass of shells. A few, however, are found in the clay seams between the stone; bones, teeth, and wood firmly imbedded in the rock, are among its most charac-

teristic indications. Small turbinated shells are frequent. If the *calcareous slate of Stonesfield* be correctly referred to this part of the series, (which is rendered still more probable by the occurrence of the same teeth and palates, in both localities,) we here find the only known instance in which the remains of birds and terrestrial animals, have been found in beds of an antiquity prior to the deluge, at all approaching to this. There they are mingled with winged insects, amphibia, sea shells, and vegetables, presenting at once the most interesting and difficult of problems connected with the distribution of organic remains. The clay above the great oolite contains few fossils except in its lowest bed, and in immediate contact with the upper surface of the subjacent oolites. In this line, it abounds with remains of the pear encrinus, with many small coralloids, and several peculiar terebratulæ.

I introduce here, an exact representation of the Lily Encrinite; a beautiful fossil distinguished by each of its arms, dividing into a hand formed of two fingers, from the inside of which proceed jointed *tentacula* (feelers); the whole folding up like a closed lily. Mr. Parkinson has some ingenious speculations on the structure and motions of this zoophyte,

illustrated by exquisite engravings—*See Organic Remains, vol. II. p.* 173.

The great Oolite.—In the great mass of this rock, perfect organic remains are rare, from the comminution which they seem to have undergone. Many small turbinated shells, like those of the forest-marble, occur here in the stone, and a bed containing numerous madrepores, several of which appear to be identical with those of the coral rag, forms a part of the series. Most of the fossils of the subjacent clay are common to the upper beds of the oolite,

Vertebral Animals. *Mammalia.*—The calcareous slate of Stonesfield presents bones, believed by M. Cuvier to belong to a species of Didelphys, or Opossum tribe. They are absolutely imbedded in the slate, along with various marine remains, and could not have been subsequenly introduced into its fissures. We have here therefore an unparalleled instance of the occurrence of animals of such an order, in strata deposited long before the superior or tertiary rocks, which are the ordinary mineral repositories of the exuviæ of the quadru peds buried so long before the flood.

Oviparous Quadrupeds. *Sauri.*—A well characterised crocodile, but of a species distinct both from all those now known alive, as also from the extinct *sauri* of Germany, and from one at least of the French fossil species, has been dug up at Gibraltar near Oxford, and is now in the collection of that university. It was taken from a bed towards the upper part of this oolitic system, probably the Cornbrash.

An immense animal, the megalosaurus, already described, as resembling the monitor, occurs at Stonesfield in the calcareous slate. This animal bears a considerable resemblance also to the Lacerta gigantea found in Bavaria and described by Sœmmering in the Munich Transactions of 1816. A translation of his memoir is published in the Annals of Philosophy for September 1821. Ammonites were found in the vicinity of this last saurian animal, as is universally the case in all the known instances of fossil crocodiles, gavials, and lacertæ. The compressed and distorted form of the head and the marks of violence apparent in many places, ought to be noticed, since they indicate some great external force to which either the animal itself at its death, or its skeleton must have been subjected since; appearances common also to the *crocodilus priscus.* What a power of pressure must have been exerted not only to flatten the conical head, but even to force out and break the teeth, as has happened to the Bavarian fossil! "If I may be permitted to decide," says M. Sœmmering, "from my own anatomical and pathological knowledge, I should say that this compression of the head was not effected during the dry, friable, and brittle skeleton state; since in such a case, owing to the equal force, the upper jaw would have been broken in another direction; or at least would not have been so perfect, as it is now on the left side. The injury appears to have been rather inflicted on the living animal when the periosteum and top of the head could hold together the fragments of the bones, notwithstanding their crushed condition.

Hence it appears to me a subject well worthy attentive examination, why it happens in all the fossil animals of antiquity, except some later ones discovered in a lighter soil, that the heads in particular are not only crushed, but at the same time dislocated in their parts. How dreadfully shattered for instance are the fragments of the head and jaw discovered at Maestricht, the jaw of the Vicentine animal, the head of the specimen belonging to M. Spener, the heads of the palæotherium and anoplotherium found at Montmartre, and the head of the *crocodilus priscus !*"

TESTUDINES.—Remains of two or three species of tortoise occur in the Stonesfield calcareous slate.

FISHES.—Teeth, palates, and vertebræ of fishes of several varieties are found both in the Stonesfield slate and in the Forest-marble of Atford near Bath : the same varieties belong to both places.

BIRDS.—Leg and thigh bones, apparently of birds, are imbedded in this calcareous slate.

INSECTS.—*Coleoptera.* Specimens pronounced by Dr. Leach to be decidedly the Elytra of Coleopterous insects occur in the Stonesfield slate. Two or three different species have been noted.

CRUSTACEA.—Two or three varieties of the crab or lobster tribe occur also in the Stonesfield slate.

All these organic remains are intimately associated with the shells which characterise this portion of the oolitic system, and cannot therefore be considered as a local, overlying, and recent deposit of animal bones. In the same beds, are found several varieties of shells, particularly a small studded tri-

gonia, and several vegetables, principally flags, ferns, and mosses.

TESTACEA. *Multilocular Univalves.*

These are the same genera for the Cornbrash, Forest marble, and clay over the oolite, as already given for the inferior oolite. For the species we refer to Mr. Conybeare's tabular list, *Geology*, p. 210. The same reference must be made as to the echinites, encrinites, and madrepores.

Irregular cylindrical branches often occur in all these beds originating apparently from *Alcyoniæ*; and in the great oolite there are well characterised fragments of these zoophytes, exhibiting distinctly their cellular and spongy texture. *See Chalk Fossils.*

Fossil wood is prevalent among all these beds, and especially in the Forest marble. In the Stonesfield calcareous slate, many beautiful vegetable impressions occur of ferns, flags, and mosses, analogous to those of the coal formation.

Range and extent.—The formations from the great oolite to the cornbrash inclusively constitute the mass of a well defined range of hills which run across the island in a diagonal direction from Yorkshire to Dorsetshire, and equal or surpass the great chain of the chalk hills in continuity, elevation, and extent. Mr. Smith has given the appropriate name of the *Stonebrash hills* to this range, from the stony fragments that are mixed with the surface soil. The Cornbrash usually forms the first acclivity of these hills where they begin to rise from the valley occupied by the Oxford clay, which accompanies them on the east and south-east; the Forest marble and calcareous slate advance still farther in the

ascent; the great oolite emerging from beneath them, forms their most elevated region and brow; and finally the subjacent beds, associated with the inferior oolite, already described, are displayed in the western slope and escarpment of these hills. The plains at their foot, are occupied by the *lias*. To the above general arrangement, there are a few exceptions caused probably by aqueous denudation.

Near Frome the horizontal beds of the oolitic series abut abruptly against the steep strata of the mountain limestone, connected with the lofty chain of Mendip, which here begins to rise. A sketch *in Geol. of Eng. p. 226*, explains how beds of such distant geological epochs as mountain limestone and oolite, come into immediate contact, in consequence of the difference of inclination through which their planes cut each other.

We have stated that this system passes across the island in a nearly continuous range of hills. Sometimes, the whole escarpment of these hills is formed by the inferior oolite, while the main oolite constitutes a slight upper terrace ranging at a distance inland. Crossing the Humber through Lincolnshire, the hills are low; they acquire more height in the counties of Rutland, Northampton, and Oxford, but the highest points in the formation are the summits rising near the edge of the escarpment (as Arbury and Epwell hills) which belong entirely to the inferior sands, the main oolite lying considerably to the south-east. In Gloucestershire, however, the great oolite always crowns the brow of the escarpment, and reaches its greatest height. The loftiest point of these hills is Cleevehill near

Cheltenham, 1134 feet above the level of the sea; Broadway, 1086; Stow in the Wold, 883; and Landsdown near Bath, 813.

Thus the hills which descend with an abrupt escarpment to the north-west, slope with a gentle declivity to the south-east. This peculiarity belongs to the chains formed by all the beds above the new red sandstone, and proceeds from the cropping out of their strata to the north and west, against the older rocks that lie in these lines of direction. The Thames which has its source on the back of the Cotteswolds on the high grounds between Cirencester and Cheltenham, wanders to the east through a course of more than 150 miles before it reaches the tide level at Richmond; while on the western side of these hills, the Severn, within twelve miles of the origin of the Thames, already feels the influence of the tide. This oolitic range, like the chalk, is completely broken through by many vallies.

The thickness of these beds varies from 250 to 400 feet. The great oolite, in common with all the beds of this formation, has a gentle dip towards the south-east. The Cornbrash forms an excellent arable soil; but that over the great oolite, is a loose, absorbent, and unproductive stonebrash.

The clays which lie under the Cornbrash and the Forest marble generally keep up the water beneath these strata, affording a ready supply of springs. Hence, as has been happily observed by Mr. Smith, the course of these beds is distinguished by a denser population, than of those of the inferior oolite, where water cannot be obtained unless from deep wells sunk at a great expense. In order to procure this

necessary of life, wells have been sunk 130 feet through the rock, till its junction with the fuller's earth, which intercepts and throws out its springs, forming a weeping soil round the escarpments of the oolitic hills; circumstances very observable near Bath. When there is a failure of this intervening clay, the springs escape downward, and are lost. This is particularly the case with the Forest marble, which has numerous swallow holes. These absorb the springs filtered through the Cornbrash. Thirty of them may be counted, within the compass of half a mile, round Hinton.

§ VII. MIDDLE DIVISION OF OOLITES.

1. *Oxford Clay.*—Clunch clay of Smith.

This clay forms the separation, between the middle and inferior assemblage of oolites, including subordinate beds of limestone called the Kelloway rock.

This formation is composed of beds of immense thickness of a tenacious dark blue clay, which becomes brown on exposure to the air. It contains argillo-calcareous geodes and septaria (balls and cakes) termed turtle stones. These geodes afford a coarse marble. The argillaceous strata are frequently blended with calcareous or bituminous matter, producing in the latter case an inflammable shale. Irregular beds of limestone occasionally appear in the lower part of this formation, which are merely subordinate. These are the Kelloway rock, in irregular concretions, hard and of a bluish colour. They consist almost entirely of a congeries of organic remains, among which several species of

ammonites predominate. The beds of clay immediately over this rock abound in selenite; below are found a brown aluminous earth and bituminous wood. Beds of clay separate the Kelloway rock from the inferior oolites.

Iron pyrites and selenite occur abundantly in this, as in all argillaceous formations. The association of sulphur with the clay strata affords a curious subject of chemical inquiry.

The organic remains of the Kelloway rock, are different from those in the clay beds.

1. In the clay, are a few bones of the ichthyosaurus, of a different species from those in the lias. Here also among testaceous remains, are ammonites, rostellaria, serpula, patella, ostrea, gryphæa, and perna.

2. Shells of the Kelloway rock.—Ammonites of different species from those in the clay, nautili, and belemnites, rostellaria, cardita, chama, gryphæa, pecten, plagiostoma, avicula, terebratula. The most characteristic shell is the *gryphæa dilatata.*

See Plate IV.; and for the range and extent of this formation, consult *Conybeare and Phillips, p.* 197.

This stratum is for the most part extremely low. Its thickness probably exceeds 500 feet, being about 700 in the midland counties. It is nearly conformable with the strata already described; its general dip being to the east and south-east under a very small angle. It is commonly necessary to sink through this dense mass before water can be found. This is a serious undertaking, a well having been sunk at Boston to the depth of 478 without success.

§ VIII. CORAL RAG,

The Superior Oolite, Oxford Oolite or Pisolite of some authors.

This formation comprises a series of beds, in all from one to two hundred feet thick; in the upper part, which contains the oolite, the calcareous matter prevails; and in the lower, the siliceous matter. The coral rag occupies the middle of the series.

The sandy, or siliceo-calcareous beds, consist of a thick deposit of yellow coloured quartzose sand, traversed by irregular strata of hard gritstone. These rest immediately on the Oxford clay. The fossils of this formation are found most abundantly in the calcareous grit of this sand, especially beneath the coral rag beds. The *ostrea gregarea*, characterises the sand. Iron is diffused through it in such plenty, as to cause the appearance of the iron sand found in a superior bed.

The remains of vertebral animals are scarce; but a few vertebræ of the ichthyosaurus have occurred in the calcareous grit.

The shells are numerous there; ammonites, nautilus, belemnites, melanea, turbo, helix, trochus, ampullaria, serpulites, ostrea, pecten, chama, trigonia, lima, lithophaga, mytilus, modiola. Many beautiful echinites are found in this formation; of the cidaris and clypeus genera. It is the first formation, in descending from the surface, which affords any considerable number or variety of madrepores. Several species of the caryophyllia and astrea are also observed. Fossil wood occurs frequently in the calcareous grit. See Plate IV.

The coral rag, which reposes on these siliceo-

calcareous beds, consists of a loose rubbly limestone, often almost entirely composed of a congeries of several varieties of aggregated and branching madrepores. There are two or three irregular courses of this rock between the freestones and the inferior sandy beds.

The upper calcareous beds are; a calcareous freestone of tolerably close texture, full of comminuted shells. It is oolitic, often with large ovoid particles, whence the name Pisolite. Colour, pale yellowish white. As a building stone, it is apt to scale off in large flakes from exposure to the weather, a defect from which the city of Oxford has suffered.

The thickness of the calcareous sand and coral rag may be estimated at about 100 feet for each. The inclination of the beds is very slight; but care must be taken in observing it, not to mistake the lines of the cleavage of the rock, for those of stratification.

From the porosity of these strata, it is necessary to penetrate to their junction with the subjacent clay, before any considerable supply of water can be had.

§ IX. UPPER DIVISION OF THE OOLITIC SERIES.

1. Kimmeridge clay. 2. Portland oolite. 3. Argillo-calcareous beds of Purbeck.

1. Kimmeridge clay. These beds consist of a blue slaty or grayish yellow clay, which contains selenite, with occasional strata of highly bituminous shale, called Kimmeridge coal, because it is

used for fuel at that place on the coast of the Isle of Purbeck. These beds are well seen on the coast of the Isle of Portland. The slate clay contains both animal and vegetable impressions. After being heated, the shale divides into large tabular masses. These beds furnish the selenites of Oxfordshire, which are constantly in progress of forming, by the union of the acid of oxygenised pyrites, with the calcareous matter of the oyster shells, and other marine fossils.

The most interesting *organic remains* of this stratum are those of the extinct genera of the fish-lacertæ. The vertebræ, paddle-fins, &c. of a species of ichthyosaurus, different from the ichthyosauri of the lias, have been observed; as also, the vertebræ, phalanges, and head, probably of a plesiosaurus. Bones like those of the cetacea, also occur. Of the shells present in abundance, the ostrea deltoidea seems most characteristic. The genera are nearly as in the coral rag. See Plate IV.

2. Portland Oolite.—Several beds of a coarse earthy limestone, compose this formation. Through all the three divisions of the oolite series, the lime-rocks are so similar, as to be distinguishable chiefly by their organic remains. All their varieties possess the character of a yellowish white calcareous freestone, mixed with a small quantity of siliceous sand, and becoming oolitic; features in which they differ entirely from the argillaceous beds. The upper series, called the oolite of Aylesbury and Portland, is fine grained, white, loose granular, of earthy aspect, with various shades of yellowish gray. Occasionally it occurs as a compact cretaceous

limestone, with a conchoidal fracture. In Wiltshire and Dorsetshire layers of chert alternate with the limestone, like flints in the chalk; while the lower beds have a sandy aspect from numerous particles of green sand.

Those varieties which are most distinctly oolitic, as at Purbeck and Portland, afford a fine building stone, much employed in London. In the Isle of Portland, the uppermost beds are numerous. They consist of oolitic rock, which at the very summit, called the cap, is yellow and porcellanous; it is fit only for making lime. The next bed is quarried for the builders; the beds below, being shelly or cherty, are employed for coarser purposes.

The following section of the quarries on the west side of Portland, was published in the Monthly Magazine for 1813, p. 481.

	Feet.
1. Vegetable mould less than	1
2, and 3. In Gosling's quarry, the stone brash and two beds of the cap are together, ...	20
4. Roach, in one bed 4 feet, and 2 other feet are united to the top of the white bed, in all	6
5. White bed, a marketable building stone, exclusive of the two feet of Roach united to it, ...	8
Many beds of flint and stony rubbish, . . .	6
6. Two other beds of Roach in the place of the middle bed of saleable stone, ...	6
7. The third bed of marketable stone, ...	6
N.B. On the side of the island this bed is of better texture, and measures from 7 to 14 feet in thickness.	
8. The above series lies on many layers of flints and beds of unserviceable stone to the depth of about .	55 or 60
The whole of the rocky strata, ...	112

Beneath is black blue shiver several hundred feet thick, of which about 100 feet stand above the level of the sea.

The beds at Portland and Tisbury contain beautiful yellow sulphate of barytes, called sugar candy stone, and calcareous spar.

The organic remains are chiefly shells. The *Amonites triplicatus* and *Pecten lamellosus* are characteristic. See Plate IV. and Geol. of Engl. p. 176.

Large fragments of wood are common, and beautiful silicified plants (*Cycadeoideæ*). See Geol. Trans. June 1828.

The soil of this stratum is a poor stone brash. The water intercepted by the subjacent Kimmeridge clay is thrown out copiously from the bottom of the oolite.

3. Purbeck Beds.

These which form the summit of the series, are composed of many thin layers of argillaceous limestone, which alternate with slaty marls, and form altogether a body 300 feet thick. According to Mr. Webster, the Purbeck stone consists chiefly of shells (principally the Helix Vivipara), partly entire and partly comminuted, imbedded in a calcareous cement, which is sometimes pure and crystalline, and at others like an indurated marl. Between these beds are interposed others free from shells, along with layers of marl and shale, which, by its shivery nature, facilitates the quarrying operations. The hill contains many alternations of these strata. One good freestone bed, worked and shipped off for London in Purbeck squares, is 5 feet thick; another a little below it, called the new *vein*, is of the same thickness. The uppermost useful stone is called the *leaning vein*. It is 7 feet thick, and affords flagstones for pavement. The only mineral contents of these beds are the pyrites of the marl stratum, and the sulphate of lime, produced by its action on the calcareous matter.

Beautiful impressions of fish are frequently found

by the quarrymen between the laminæ of the limestone, as also fragments of bones, belonging chiefly to the turtle. Complete fossil turtles have also occurred, of which one specimen was found in great perfection. The shells of this formation have not been accurately examined. The Purbeck beds have an average total thickness of about 300 feet. They are retentive, and must be sunk through for water.

None of the above formations of the upper division of the oolite series, have been noticed hitherto to the north of Buckinghamshire. Here the Portland beds first make their appearance beneath the iron sand, forming a constituent of the same chain of hills. It underlies a great part of the vale of Aylesbury. On the borders of Oxon and Bucks, it rises from Thame, and culminates on the insulated group of Brill hills, with a thin covering of iron sand. It passes thence to the south-west, and again culminates at Shotover. Through the north of Dorsetshire, the prolongation of this series is concealed by the projection westwards of the vast overlying platforms of chalk and green sand extending over their basset edges or outcrops. Beyond the escarpment of the chalk it reappears.

The strata of the isle of Purbeck district are inclined to the horizon, and are perforated with caves at its western extremity. There the Portland beds, dipping inland in an angle of from 45 to 60 degrees, form the exterior barriers and capes at the mouth of these coves, while the vertical strata of the high chalk downs range along their bottom. The more solid masses of the Portland rock having most powerfully resisted the destroying agents which

seem to have excavated the coves, often form a reef of rocks in advance. In the convulsions of the strata the solid beds of Portland rock have been lifted up in mass, in regular inclined planes; but the softer superincumbent argillaceous beds have been bent by the lateral pressure into many curious contortions, such as we formerly described in treating of the primitive and coal formations. It may indeed be admitted as a general fact, that when thick and compact beds of stone are associated with thin yielding beds, in a series of inclined strata, the stone, however much it may be raised, retains its flat planes of stratification, while the tabular clays are bent and twisted into the most irregular curves. This disposition affords demonstrative evidence of the beds having been upheaved and dislocated by mechanical violence after their horizontal deposition.

The average height to which this formation rises is about 500 feet. The isle of Portland is 300. In general, these beds are nearly horizontal, where they have suffered no eruptive violence. But from this force, in the vale of Nadder, they are elevated sometimes to an angle of 45°; while at Upway and Portland they decline in opposite directions, forming a portion of what has been called the Weymouth saddle. See Geol. of Eng. *Fig. p.* 192.

§ X. BEDS BETWEEN THE CHALK AND OOLITE SERIES.

This interval may be regarded as filled up by a series of beds chiefly of siliceous sand, which possess an aggregate thickness in the greater part of their course of about 1000 feet. They form the

extensive tract of sand universally traceable beneath the escarpment and inferior termination of the chalk ranges. This series is exhibited in the clearest manner in the southern counties of England;—the middle and northern have not been so well explored. The sandy beds are divided into two groups, with an interjacent stratum of clay. The upper sandstone is interspersed with numerous specks of a greenish substance; the lower has a deep ferruginous hue, from brown oxide of iron. Hence the first is called the *green sand;* the second the *iron sand* formation. The upper bed is parted from the chalk by argillo-calcareous strata, but their line of division is not very well marked on account of the graduation of the lower chalk into them. These mixed beds have been called chalk marl. Reckoning from below in the order of superposition, we have therefore,

1. Iron sand.
2. Interjacent clay, which being found extensively in the Wealds of Kent, Surrey, and Sussex, is called Weald clay.
3. Green sand.
4. Chalk marl.

All these strata are probably of marine origin. Formations similar to these in England, are found skirting the chalk of Boulogne, at its western limit about Honfleur and Havre, and its eastern boundary at Valenciennes; where the green sand assumes a conglomerate appearance, and is called *turtia.* Analogous formations have been observed in Switzerland. It is probable that the sandstone of Saxony, called Quadersandstein, belongs to the same series.

In other parts of the world, we possess no means of tracing these beds.

1. *Iron or Hastings Sand.*—This formation may be studied with most advantage in the neighbourhood of Hastings. It consists of a series of strata in which sand and sandstone prevail, alternating occasionally with subordinate beds of clay, marl, fuller's earth, and ochre. The sand is entirely siliceous, and contains iron in such quantity as formerly to have rendered it worth working as an ore of that metal. The sandstones often form coarse grained conglomerates, which consist of pebbles from the size of a pigeon's egg to a pin's head, imbedded in a ferruginous cement. Thence a regular gradation may be traced to a very fine grained sandstone, affording flags for pavements and for building stones. Ferns, charred wood, and other supposed associates of coal, occur in the white and gray sandstones of this series, but rarely in the ferruginous. The beds of fuller's earth which occasionally alternate here, have been extensively worked in Bedfordshire. The ochre of Shotover hill occupies a similar geological position.

The organic remains of this bed have been imperfectly explored. They are not numerous; but the nautilus, belemnites, ammonites, ostrea, terebratula, and spines of an echinus cidaris have been found. The most abundant fossils are the spongitæ, of which many varieties, tubular, funnel-shaped, and palmated occur. The richest locality is at Farringdon in Berkshire. Beautiful minute corallines have been also observed.

In the west of Cambridgeshire this formation is

well exhibited, and it may be traced thence throughout the southern part of the island. In the midland counties it constitutes the mass of a chain of hills extending through Bedfordshire, and forms the summits of the same chain which ranges through Bucks, Oxon, Berks and Wilts. Its greatest thickness appears to lie in the Weald country, where it amounts to 500 feet. In inclination, its strata conform to those of the chalk which lies over it. It constitutes in many places a fertile soil, and is favourable to the growth of wood. Like all other loose and porous mineral masses, which are divided by a few tenacious layers, this formation can furnish water only at such partitions; and hence the wells are here deep, and from the abundance of iron they are chalybeate. Tunbridge Wells is a notable instance.

2. *Weald Clay.*—This is exhibited on the largest scale in the Wealds of Kent, Surrey, and Sussex, where it separates the central nucleus of ferruginous sand from the encircling ranges of the green sand strata. This bed varies in quality from a dark tenacious clay, to a blue or gray calcareous marl of an earthy and friable texture. Layers of argillo-calcareous concretions occur replete with shells of the genus *Vivipara fluviorum.* Their interior is filled with calcareous spar; which when cut and polished is called Petworth marble. Its organic remains have not been enumerated; nor can we infer any thing as to the formation from the above single shell. In the Weald of Kent the thickness of the bed is about 300 feet; in the Isle of Wight only 100.

3. *Green sand.*—This formation is one of the

most important between the oolites and chalk, both from its mass and the number and beauty of its organic remains. In the southern counties of England the bed is thick and easily traced; but it is more obscure in the midland and northern. The green sand is siliceous, and is sometimes consolidated into sandstone with a calcareous cement. The nature of the green earthy colouring matter is not well known. It is probably some form of iron, along with micaceous particles. There are subordinate beds and masses of chert, and veins of chalcedony; with alternating beds and nodules of limestone called Rag in the Isle of Wight. It is the Kentish rag. This limestone is perfectly distinct from that of Portland in geological position, character, and fossils. There are occasional parting seams of clay. Iron pyrites occurs in this rock at Folkstone, and hematitic iron in the ferruginous beds. Crystallized sulphate of barytes of a yellow colour, with its interstices filled with opaque quartz, has been observed.

Organic Remains.—These are extremely numerous. At Blackdown, and other places, they occur in a state of beautiful preservation, imbedded in the siliceous varieties of the rock, the original calcareous matter of the fossil being entirely supplanted by chalcedonic infiltration. The quarries of Blackdown afford 150 species of testacea. Under the family *Echinus* we have the divisions cidaris and spatangus, and one small species of conalus. This formation is the lowest in which the spatangi have hitherto been found in England; and the only one besides the chalk, that seems to contain the

conalus. The *encrinites* are few and unimportant; as well as the coralloids. The alcyonic remains are however both more numerous and important in this formation than in any other except the chalk. We have the ramose; the funnel-shaped (figured in the frontispiece to Parkinson's Organic Remains); the tulip shaped; one with a large head divided into many lobes, standing on a short neck; one shaped like a cucumber. Silicified wood also occurs.

This formation may be traced very extensively beneath the chalk. In Wiltshire it constitutes hills standing in advance of those of the chalk formation, and nearly equalling them in height. On the confines of Dorset and Devon it occurs in high and insulated masses, called outliers. In the course of its progress to the south-west, the green sand successively overlies the terminations of the oolites and the lias; becoming immediately incumbent on the newer red sandstone, in the western part of Blackdown. Through the isles of Purbeck and Wight, it attends the elevated strata of the chalk, with a conformable inclination. Its hills do not exceed 800 or 900 feet. Its thickness is in many places 200 feet. It forms a light loamy soil, of considerable fertility. From its porous nature, it is often necessary to pierce it deeply before we reach the water kept up by the retentive substratum of Weald-clay.

4. *Chalk Marl.*—This formation consists apparently of three ingredients intimately mixed; 1st, cretaceous matter; 2d, argillaceous matter; 3d, sand. The cretaceous matter is harder than chalk, is laminated, and will not mark like it. Its colour is gray or mottled, and it falls to pieces when wetted

and dried again. Where the argillaceous matter predominates much, a tenacious clay marl of the ordinary characters, and bluish-gray colour, is the result. And when the sand is in excess, a fine-grained grayish sandstone of loose texture is produced, which forms a connecting link with the green sand below. The more argillaceous form contains 30 *per cent.* of carbonate of lime ; the more cretaceous 82, with 18 silex and alumina (chiefly the former), and a trace of iron. Beds of chert are occasionally found in these strata as at Reigate, and flinty nodules in some parts of Cambridgeshire. The upper cretaceous beds, near the junction with the chalk, contain organic remains of nearly the same description as those of the lower chalk, viz. nautilus, inoceramus, *echini*, *alcyonia*, and sponges. The lower and more argillaceous strata are distinguished by a great variety of singular fossils, especially multilocular shells. We have several species of ammonites, nautilus, hamites, scaphites, turrilites, belemnites, dentalium, vermicularia, cerithium, euomphalus, patella, terebratula, arca, nucula, pecten, inoceramus, a variety of spatangus, madrepores, and pentacrinite. Remains of vertebral animals are not common ; but of wood, numerous fragments are found with the ligneous fibre. The breadth of this tract is generally from one to two miles ; and its thickness from 300 to 400 feet. The strata are conformable in inclination to the superjacent chalk, and therefore commonly horizontal, but in the disturbed ranges of the isle of Wight and Purbeck, they are thrown into an upright position. See Plates IV & V.

§ XI. THE CHALK FORMATION.

This stratum forms by its extent and distinctive characters one of the most remarkable mineral features of England. It would seem as if an interval of time had elapsed between the completion of the chalk beds, and the deposit of others upon it; for the surface of the chalk at its boundary with the superincumbent layers, bears marks of having undergone, during that period, a partial destruction after it was consolidated. There is spread over it, a stratum of debris, consisting chiefly of flints washed out of its mass. Moreover, the surface is irregularly worn into numerous cavities, of which many are deep, and filled up with the same debris. At the junction of the chalk with the sand and gravel of the plastic clay formation, deep indentations are observed on its surface, which are sections of long furrows and cavities apparently produced by the action of agitated water on the chalk before it was protected by the covering of clay.

The enormous quantity of chalk-flint pebbles completely rolled and rounded which are found in the plastic clay to the south of London, show that the chalk itself must have been consolidated before that partial wasting of its upper strata by water. To this hydraulic action, MM. Cuvier and Brogniart ascribe the irregular ridges and furrows on the surface of the French chalk, and the Meudon breccia. The immense scale on which this destruction was carried on may be inferred from the vast extent of the English pebble beds. That a long period of time probably intervened between the deposition of the chalk, and of its clay coating, is

rendered probable also by the total difference of the organic remains found in the two strata. By such wasting causes the chalk must have been reduced to much narrower bounds than it occupied at first. On the north of Northamptonshire, on the borders of Rutland and Leicestershire, and in the vale of Shipstone in Warwickshire, accumulations of chalk flints, mixed with rounded fragments of hard chalk, occur in such quantities as to warrant the idea of this formation having once covered these districts, now 50 miles distant from its nearest line. The transition from the chalk to the more recent deposits appears to have been sudden, not gradual. In a few cases indeed a bed of intermediate character, a cretaceous marl, lies between them; which tends to show that where the series of deposits was permitted to proceed quietly, such a gradation might have gone on.

The band of chalk which stretches across the eastern and southern counties of England from Yorkshire to Dorsetshire is to be regarded merely as the western edge of a most extensive tract of this formation. Stretching from the Thames to the Don the chalk occupies the interior area of the great central basin of Europe. This concavity is bounded on the north by the primitive mountain districts of Russian Finland, Sweden, Norway and Scotland; on the west by the transition and primitive chains of Cumberland, Wales, Devonshire and Brittany; on the south, by the primitive mountains branching from the Cevennes in the centre of France, the Alps, with the various grand groups of Germany, as the Black Forest, the Rhingau, and

the Vosges, the Bohemian, Thuringian, Saxon, Silesian and Carpathian mountains; on the east, by the Ural chain and its branches. The chalk does not rest on the mountains themselves; but within the area which they circumscribe at a certain distance from them, an interior area may be traced, over which the substratum of chalk is believed to extend.

Through the northern coasts of France it occupies an extent exactly corresponding to its line on the southern shores of England. At the north of the Seine, its outer edge, reposing on green sand, turns south, and runs on to Blois, where the deposits above the chalk overlie and conceal its southern extremity. It re-appears at Montargis, and bending again northward, forms a sort of promontory, passing east of Troyes, Rheims, and Valenciennes, having the green sand, oolites and lias cropping out further eastward. At Valenciennes, most of these formations are wanting, and the chalk, with a few beds of green sand (there called *Turtia*), repose horizontally on the truncated edges of the coal basin, extending along the banks of the Meuse to Liege and Aix. Here the coal is therefore worked beneath the chalk. Hence the chalk may be considered as ranging beneath the sandy and diluvial tracts of North Germany towards Berlin. The whole of this territory is a vast sandy heath, covered with a deep detritus of diluvial gravel, in the midst of which occur enormous rounded blocks of granite, traceable to the opposite shores of the Baltic, exhibiting one of the most sublime phenomena of geology. Nine-tenths of this gravel are

chalk flints; and Mr. Conybeare had the sagacity to discover about half-a-mile from Luneburg, on the way to Hamburg, a chalk pit which had escaped the attention of former observers. It contains the usual alternation of flints, along with good specimens of the *inoceramus*, *echinites*, and most of the characteristic chalk fossils. On entering Poland, the chalk lays aside the cloak which had for a space concealed it, and re-appears in a line of hills nearly parallel to the Carpathians. It is finely displayed at Cracow, where it reposes on green sand, and exhibits flints in abundance, with the customary organic remains. Passing thence by Lemberg, it appears to stretch into Russia. Dr. Clarke noticed hills of chalk on the Don. The town of Bielogorod (white city), takes its name from white chalky hills in the neighbourhood. Chalk with its usual flints and fossils, was observed by Engelhardt, even in the Crimea. Chalky cliffs are seen on the northern coast of the Island of Rugen, and on the opposite shore of the Baltic in Pomerania and Mecklenburg. A chalk tract occurs near Malmo in Sweden. The chalk is supposed to traverse Holstein, to the mouth of the Elbe, and thence crosses the German Ocean to Flamborough-head in Yorkshire. Thus is completed its great circuit.

This extensive chalk tract presents a remarkable uniformity of geological character; and proves the general action of the causes which produced mineral deposits. The organic remains also, to the amount of, at least, eight-tenths, are common to all the localities in which chalk has been recognised; as in England, France, the Netherlands, Germany,

and Poland. Mr. Conybeare says he has never seen a fossil from any foreign chalk-pit to which an analogue might not be produced from the pits of this island. These are important facts. They demonstrate that formations in very distant regions admit of comparison on satisfactory principles ; and illustrate the value of organic remains in establishing these comparisons.

Partial chalk tracts occur beyond the precincts of the preceding European area. A remarkable deposit of chalk forms the basis of the great basaltic area in the north-east angle of Ireland. It contains flints, agrees in its organic remains with England, and rests on green sand (called Mulatto). The thickness of that deposit does not exceed 300 feet.

It is remarkable that America, both South and North, seems to be destitute of chalk ; Mr. Maclure asserting positively that it does not exist on that continent.

Chalk is well known to have an earthy dull fracture and a meagre touch, but it occasionally concretes into a hard limestone. This compact chalk has been used in building. As this formation is composed throughout of a series of homogeneous beds of a tender earthy limestone, it does not admit of stratiform subdivisions.

But the numerous beds of nodular flints which lie alternately distributed through the greater part of its mass, form one of its most curious and essential features. They are constantly present in all the upper portions of the formation, but are frequently absent in the lower ; affording a criterion by which

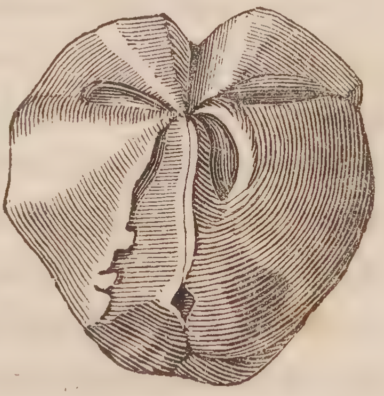
the two may be distinguished. Hence the meaning of the terms *upper* and *lower* chalk. Flints freshly taken from their native bed, exhibit in their fracture an appearance of moisture. They have indeed been produced most probably by the infiltration of siliceous water through the particles of silica originally deposited among the chalk, some of which are still to be discerned. We can see chalcedonies now forming by the percolation of water through siliceous substances. The presence of a sponge or alcyonium seems to have been peculiarly favourable to the formation of chalcedony in chalk. Wherever chalcedony occurs in flint, a careful examination will detect traces of these zoophytes. Beautiful figures are often produced by their ramifications, radiating through the chalcedony; appearances which become more visible when this hydrophanus stone is plunged in water.

Iron pyrites is the only mineral substance common to all the chalks, and it is found in most, if not all the beds, where it varies in size from a pea to an orange. The nodules are crystalline, with a fibrous and diverging fracture. Enormous blocks of carbonate of lime occasionally occur.

Organic Remains.—The individual exuviæ though numerous, belong to a few genera; and probably not a single species will be found, identical in all its characters with any now known to exist. Among the remains of vertebral fish, we may specify teeth of a species of shark, perhaps akin to the *squalus galeus*, two varieties of the grinding palatal bones belonging to unknown genera, with vertebræ, and scales. Of multilocular

univalves we have the following genera; ammonites, scaphites, belemnites; but the first rarely occurs in the upper chalk, and the second only in the lower. The varieties are peculiar and characteristic of these beds. There are few spiral univalves in the chalk; though they abound in the newer beds above it. The genera trochus, cirrus, and turbo are mentioned. Serpulæ and spirorbes are not uncommon. Ostrea, pecten, terebratulæ, magas, plagiostoma, dianchora, inoceramus, are genera of bivalves which occur; the four last being extinct. A species of *balanus*, of the multivalves, has been found. See Plate V.

The echinite family comprehending spatangus, cidaris and ananchytes, may be deemed characteristic of the chalk formation, affording of itself as many shells as all the other testacea do. Many species, and one entire genus are peculiar to it. Thus we have the helmet shaped, the conical, the heart-shaped *Spatangus Cor anguinum*, (see figure on margin;) the spheroidal, the cidaris papillata, cidaris variolata; See Plate V. Of the star-fish (asterias) 4 species are figured by Mr. Parkinson as belonging to the chalk in his beautiful representations of organic remains.



Of the zoophytes, the family encrinus has left several genera in the chalk; pentacrinus; straight encrinus; bottle encrinus; stag's horn encrinus; which are all extinct.

The tortoise encrinus, or marsupite also occurs.

It is known merely as a fossil, and is peculiar to the chalk.

Only one species of the family madrepore has been observed.

Numerous exuviæ have been found of the families *Alcyonium* (see figure on margin), and *Spongia*. Their interior substance consists of interwoven fibres, penetrated by pores, formed by reticulations which sometimes run confusedly together, and which at others are regularly decussated.

The chalk formation of England stretches with little interruption from Flamborough-head to near Sidmouth, forming a range of hills which are often pretty high, with their precipitous escarpment generally on the north-western side. These cliffs exhibit at their summit the superior soft chalk, replete with horizontal layers of flint: and at their bottom, hard chalk with few flints. Magnificent arches open into the mountain mass of Flamborough-head, on the north, forming vast porticoes to its immense caverns, some of which are exceedingly sombre, while others give a cheerful and romantic passage to the light. In the Yorkshire and Lincolnshire wolds, the chalk tract has an average breadth of rather more than six miles. From Bridlington Bay the chalk proceeds inland, and rises into hills, which have nearly a western direction for about 15 miles, with their escarpment facing the north. These hills then turn southward, and terminate at the Humber. Near the easternmost point of the Lincolnshire coast, the chalk dips

beneath *alluvium,* whence it re-appears on the north-western point of Norfolk, adjoining the Wash. From Cambridge, the western limit, it runs south-west, rising at Rayston-downs into a range of hills which continue through Herts, Bedfordshire, and Buckinghamshire to Goring in Oxfordshire; a distance of about 75 miles, with an average breadth of 15 miles. It is there crossed by the valley of the Thames. From the summit of its north-west escarpment, it declines gradually to the south-east, and dips beneath the upper bed of the London basin. On the west of the Thames, the chain is continued to Marlborough-downs, and thence to Bagdon-hill in Wilts. It is thus connected with the cretaceous district of Hampshire, being 50 miles in its longest diameter. Its shortest from north to south, is about 20 miles. This vast area is the central chalk region, from which its branches diverge over the island. The hills above Selbourne form its limits on the east; those skirting the vale of Warminster on the west, and on the north, Inkpen-hill to the south of Salisbury; its highest summit is 1011 feet above the level of the sea. Much of the area thus circumscribed lies in Salisbury plain. Another chain is detached from the north-east angle of the great central mass near Farnham, extending to the Straits of Dover near Folkestone to form the North Downs of Surrey and Kent. This chain bounds the London basin on the south, as the former did on the north. Its escarpment runs from west to east by Guildford, Dorking, Seven Oaks, Maidstone, Folkstone, and the cliffs of Dover. The highest point is at Botley-hill.

The Isle of Thanet, though wholly chalk, is not connected with the preceding chain, but is separated by a trough filled with the materials of the upper strata, out of which its beds rise towards the north-east. Between Beachy-head, and Brighton, the coast section of the chain exhibits a magnificent range of chalky cliffs. This chain descends to the south beneath the tertiary strata, which occupy the basin of the Isle of Wight. These are bounded on the north-east by the chalk. Here it is known by the name of the South Downs, being on an average about 5 miles in breadth. Its highest point is Butser-hill in Hampshire, 917 feet above the level of the sea.

From the south of the great central mass near Salisbury, a chain of the chalk is detached through Dorsetshire, to bound the Isle of Wight basin on the north-west. It extends to the north of Beaminster, forming Horn-hill, which is its extreme point of connexion in the west of England, exclusive of a few outlying masses, reposing upon and surrounded by beds of green sand. At the peninsula of Purbeck, the chalk which lies usually in horizontal beds, assumes a nearly vertical direction, exhibiting at Handfast point some of the most singular phenomena in stratification which geology has described.

The chalk formation presents considerable undulations of surface, rising occasionally into hills remarkable for their smooth rounded outline, and deep lateral hollows and indentations. These hills have a precipitous escarpment on one side, which in the Yorkshire and Dorsetshire range is to the north-west, with a gentle slope to the south-east.

The ranges are frequently broken through by transverse valleys, the manner of whose connexion with the longitudinal valleys at the foot of the chain, proves that they have not been excavated by the action of the rivers now flowing through them. They are evident results of diluvial waters scooping out in their retreat wide troughs among these semi-indurated lands.

The aggregate thickness of the upper and lower chalk is estimated by Professor Buckland at 580 feet, each of the two beds being almost equally thick. Near Dover, however, the flint-chalk is 480; that without flints is only 140; at Handfast point, the former is 600, and the latter 200 feet. In many places the total thickness is 1000 feet. In digging wells, the chalk has been frequently pierced very deeply; near Rathby in Lincolnshire, to 300 feet; in Bedfordshire, to 400; in Kent near Sittingborne, to 363; in Surrey near Dorking, to 440. But we do not know that any of these perforations have passed through the chalk. The dip of the chalk beds is in general inconsiderable.

The flinty chalk forms everywhere the upper layer of this great deposit.

Messrs. Cuvier and Brogniart represent the chalk deposit as forming a sterile soil; and adduce Champagne as a proof of its being in some cases uninhabitable. In our country, the population of the chalk district is less dense than that of any of the other secondary strata, but it is always habitable, and therefore productive in some degree. Dunstable Downs and Luton Downs in Bedfordshire, with the Warden White Hills, lie indeed as nature left

them over a tract of 400 acres. The chalk valleys, however, are often extremely fertile; of which the Kent and Surrey hop grounds, and the Downs for pasturing sheep, afford examples. Beech is the tree best fitted for a chalky soil. The Chiltern hills in Oxfordshire, were anciently covered with thickets and woods of beech, which afforded harbour to banditti. Hence the steward of the Chiltern hundreds, formerly an employment under the crown, has become a nominal office, which members of parliament take under a fiction of law, in order to vacate their seats.

The lower beds of the chalk formation, are with few exceptions filled with water, which percolating from above is arrested by the subsoil of blue clay. Thus are formed the springs and rivulets which issue near the foot of every chalk hill. Most of the rivers which traverse this formation, rise in the older rocks beyond its escarpment, and flow along the valleys that are excavated across its chain. The chalk is often nearly dry to a great depth; the well sunk 400 feet at Royston in Hertfordshire, afforded no water. For particular views of the sections of the chalk formation, throughout England, I refer to Messrs. Conybeare and Phillip's excellent work, p. 89, *et seq*.

On the coasts of France opposite to the English chalk country, a series of sections may be observed almost exactly answering both in character and position to those now briefly traced, but fully described in the above work, demonstrating that the constituent strata had been continuous at some ancient epoch. The corresponding points between

the cliffs on each side of the Straits of Dover are too remarkable for us to esteem their former continuity an hypothesis. That the connecting mass has been apparently washed away by an irruption of the sea, may be inferred from the fact that the chalk without flints on the west of Dover is not less than 50 feet in thickness, while that of Cap Blanc Nez is scarcely 30 feet thick, while each of the superjacent strata is thinner in the same proportion on the French point, that at Dover. Hence the heights of the cliffs on the opposite shores is very different; that immediately on the west of Shakespeare's Cliff being at least 500 feet, while that of Cap Blanc Nez is not more than 300. It may therefore be concluded that the strata in the neighbourhood of Calais once constituted a part of that tract now termed the chalk basin of London. The chalk chains between the two countries may have had originally a lower level than on either side, whence the work of excavation would be easier.

From the low and marshy grounds near Calais, between that town and Uisant a range of chalky cliffs faces those of Dover, exhibiting like interior subdivisions; viz. 1, Chalk with flints on the summit of the cliffs; then, 2, Chalk with few flints; 3, A bed with organic remains; 4, Chalk without flints; 5, Gray chalk. *The strata rise under a low angle westward, and near St. Pol, as at Folkstone,* are succeeded by the substrata of blue marl, and green sand. At Treport, about 12 miles eastward of Dieppe, the principal range of the chalk cliffs on the French coast commences, from which point, they extend about 60 miles to Cape La Heve near

the mouth of the Seine, exhibiting a broken barrier of a dazzling white. Near Cape de Caux, are some remarkable insulated pyramids of chalk resembling in form and circumstances the Needles of the Isle of Wight. They are also called les Aiguilles. The most lofty and striking point of these cliffs is at Fecamp, where the height is about 400 feet.

CHAP. V.—STRATA ABOVE THE CHALK, OR TERTIARY ROCKS.

These consist of various beds of sand, clay, marl, and imperfectly consolidated limestone. They occupy two extensive tracts in England, each circumscribed by the hills of the chalk formation, excepting where the line of sea-coast crosses their areas and conceals their continuation. The most northerly of these subjacent chalk strata is denominated the London basin, the southern is the basin of the Isle of Wight. The boundary of the first of these basins may be defined generally by a line drawn from the inner edge of the chalk, south of Flamborough-head, nearly southward till it crosses the Wash, then south-west to the upper part of the valley of the river Kennet near Hungerford in Wiltshire, and thence tending south-east to the north of the Thames, and the north-west angle of the Isle of Thanet. In all these directions, the chalk hills form the outline; while the German Ocean is the eastern boundary. The Isle of Wight basin is similarly circumscribed by chalk hills.

The Tertiary Rocks are as follows :

I. Plastic Clay, immediately over the chalk.
II. London Clay.

III. Fresh Water formations.

IV. Upper Marine formation; Crag and Bag-shot sand.

§ I. PLASTIC CLAY FORMATION.

Viewed as a whole this formation consists of an indefinite number of sand, clay, and pebble beds, in irregular alternation. In England, the sands are the most extensive of these deposits; among which the clay and pebbles are subordinately placed at unequable intervals. On attentive investigation over a wide surface, these alternate layers above the chalk, will be found to form only one nearly contemporaneous series, between the chalk and the London clay. The plastic clay of the Paris chalk basin consists commonly of two beds separated by a stratum of sand, of which the lower is properly the plastic clay. It is unctuous, tenacious, with some siliceous matter, but no calcareous, and quite refractory in the furnace, provided that there be little iron intermixed. Its colour is very variable; white, gray, yellow, gray mixed with red, or almost pure red. The clay is used according to its quality, for fine or coarse pottery. The French sands have a great variety of colours. In the lower strata of the Paris plastic clay bed an imperfect coal occurs.

In England the sands of this formation are in some places of an almost infinite variety of colours, as at Alum Bay on the coast of the Isle of Wight, and it is sometimes aggregated into sandstone. The clays differ in colour and quality, and are sometimes laminated. They are called fire-clay, brick-clay, pipe-clay, and potter's-clay; the two latter occur at Poole and the Isle of Wight. Beds of

wood coal have been observed in the Isle of Wight, in Dorsetshire, and at Newhaven ; and fuller's earth in the beds at Catsgrove near Reading, and on the Edgeware road. In all these particulars, a close analogy exists between the French and English basins.

Pyrites, selenite, fibrous gypsum, and tubular ironstone, are the mineral contents of this formation. They occur in veins. There are also nodules of a dark coloured limestone.

Among the organic exuviæ of the plastic clay beds, we have, ostreæ, cerithiæ, turritellæ, cythereæ, cyclades, &c. along with the teeth of fish, woody fibre passing into coal, occasionally exhibiting unchanged branches and leaves of plants. Fossil bones have been also noticed in it, near Margate. These exuviæ are as irregularly distributed, as the constituent layers of the formation itself; for they appear sometimes in the clay, and sometimes in the sand and pebbles, and are often absent. Thus, for example, we find no vestige of animal or vegetable bodies in any of the strata of the plastic clay at Reading in Berkshire, except in the occasional green sand. The same barrenness is to be observed in the purest plastic clay of Paris, and of the Isle of Wight and Corfe Castle.

Mr. Webster has ascertained that the vegetables in this formation at Newhaven, agree with those found in the Paris basin. One of them was the fruit of the palm-tree, furnishing another instance of the presence in our cold strata of the exotics of a hot climate. This formation visibly discovers itself as superjacent on the London chalk, and is seen to skirt the whole strata of the London clay which

covers it. For the range and extent of the English plastic clay, see *Geol. of Eng.* p. 39. The thickness of this formation does not seem to have been ascertained in many points. Chalk has been found beneath its surface near Wormley Bury in Hertfordshire, just beyond the boundary of the clay, at 100 feet below the surface, which appears to be its thickness also near London. Round Woolwich it sometimes amounts to nearly 200 feet. In the Isle of Wight, the apparent thickness is no less than 1100 feet, which is probably from being squeezed up by violent lateral pressure, into a vertical position, a result quite compatible with the loose state. (Fig. Conyb. pl. 2, fig. 6.) In dip, the plastic clay usually conforms to the subjacent chalk. The following downward section of strata at Catsgrove hill near Reading, will give an accurate idea of the tertiary formations, and the plastic clay beds in that locality.

SECTION OF CATSGROVE HILL, NEAR READING.

	Feet.
1. Alluvium of clay, sand and gravel, covered with vegetable mould.	
2. Soft loam, of soft sand mixed with flakes of ash-coloured clay, with much iron shot and pyritous nodules in the lower portions,	11
3. Dark red clay partially mottled and mixed with gray clay, .	4
4. Light ash coloured clay, mixed with fine san d; used for bricks,	7
5. Fine micaceous sand, laminated, with clay and iron-shot; used for making tiles, ...	4
6. Bed called the White vein. An ash-coloured sand, mixed with a little clay; used for bricks, ...	5
7. Dark red clay mottled with blue, with a little iron-shot; used for tiles, ...	6
8. Lowest brick clay, of a light gray colour, mixed with fine sand, and a little iron-shot, ...	5
9. White sand used in brick making, ...	4
10. Fuller's earth, ...	3
11. Yellowish quartzose sand, with a few green particles, . .	5

12. Siliceous sand mixed with particles of green earth, containing chalk flints, both angular and rolled, oysters, with many small and nearly cylindrical teeth of fish, from an inch to 1-12th in length, ... 3

57

13. Chalk containing the usual fossils and flints, depth unknown.

The red clay of Reading (No. 7.) is quite identical with that of Meudon in France. The oyster shells of No. 12 are remarkably perfect when first laid open, and seem to have suffered no mineralisation; but they soon fall to pieces on exposure to air, having lost their albuminous cement. The angular flints seem to have proceeded from the partial destruction of the immediately subjacent chalk, the upper surface of which in contact with the sand is considerably decomposed to the depth of about a foot. Its fissures and numerous small tubular cavities, probably caused by the decay of organic substances, are filled with granular particles of the green earth and siliceous sand of the incumbent stratum. Many of the subdivisions noted in the above section, do not appear in other places, showing the irregularity of the interior distribution of the strata. Several other instructive sections will be found in the *Geology of England, p.* 44, *et seq.*

§ II. LONDON CLAY.

This great argillaceous formation is highly interesting from the variety of its organic remains, both animal and vegetable, and from the conclusions which these warrant, that as their species can be completely identified in but a few instances with recent analogues, the London clay is therefore a much more ancient deposit than the beds imme-

diately over it, which do contain specimens of existing species. The same inference follows from the London clay having been raised into a vertical position in the Isle of Wight, while it lay uncovered; for the upper beds now repose horizontally on its truncated upright edges. It must have lain a sufficient time to acquire solidity before being so lifted up, and covered with the newer horizontal deposits.

This formation is composed almost wholly of bluish or blackish clay, of a very tough quality. A few of its strata, indeed, are sometimes of a marly nature, effervescing somewhat briskly when immersed in an acid. It contains a great deal of green earth in the Isle of Wight; considerable beds of sandstone occasionally occur, as the Bognor rocks, the Barns rocks, the Roundgate and Street rocks, and Mixen rocks to the south of Selsea. Beds of stratified limestone appear in the clay cliffs near Harwich in Essex. The following section of a well at Twyford near Acton in Middlesex, will show the interior structure of this formation.

SECTION OF LONDON CLAY.

	Feet.
1. Yellow clay,	38
2. Lead coloured clay, containing some fossil wood at 188, and shells at 200 feet from the surface,	170
3. Rock, 4. Sand and clay with pebbles,	2
5. Variegated clay, red, blue and black,	32
6. Sand and water, thin.	
7. Clay.	

The section at the Highgate tunnel, disclosed the following strata.

	Feet.
1. Diluvial detritus consisting of flint and gravel, sand, and loam, occasionally concreted by iron, . . .	10
2. Loam with a few marly concretions, but no septaria, pebbles, or shells, ...	30
3. Blue clay with septaria and shells, hardest in the lowest layers, ...	65
	105

The *calcaire grossier* of the Paris strata, which lies immediately under the surface of the soil and diluvium, corresponds most nearly in its fossils, and its geological relations, with the London clay of the English series. It is used in that capital as a building stone. No beds have been discovered in the London basin which make a nearer approach to the French lime-crag in chemical and external characters than the calcareous sandstone patches above mentioned.

Whenever the London clay occurs in a cliff, or has been laid open in sinking wells, it has been found uniformly to contain nearly horizontal layers of ovate or flattish masses of argillaceous limestone. These have been called *septaria*, because they generally exhibit the appearance of having been traversed in various directions by fissures, afterwards filled up wholly or partially by calcareous spar or sulphate of barytes. They were considered at one time as characteristic of the London clay; but they are not uncommon in the superficial clay beds of coal districts. They abound in such a degree in the lias at Whitby, as to have acquired for the stratum in which they lie, the name of cement stone, as already mentioned under that head.

The London clay, therefore, is a vast argillaceous deposit, containing subordinate beds of calcareous

concretions, which sometimes form solid rocks, but these partial changes, never affect the general character of the formation.

Interspersed through it, we find sulphuret of iron, selenite, and sometimes phosphate of iron, substances which impregnate any water which issues from this stratum, and make it unfit for domestic use. The mineral copal or resin which was discovered in excavating Highgate archway, though manifestly a vegetable product, may, in its fossil state, be classed among the contents of this formation. In the gravel about London, amber has also been found, as also in the cliffs of brown clay on the coast of Holderness, in the south of Yorkshire. It may most probably be assigned to the London clay, since it occurs in the contemporaneous formations of Europe, in Italy, France, and especially Prussia, associated with a vast quantity of vegetable remains.

Few mineral strata claim a greater interest than this formation does, by its organic remains. Among the amphibious class of the higher orders of animals, we find here crocodiles and turtles; proving that the shores of some dry land, where these creatures could deposit their eggs, must have lain within an accessible distance of their abode. Several species of vertebral fish, are found in fine preservation, which merit the study of the comparative anatomist. Among crustaceous fish we may enumerate species of the crab and the lobster.

The testaceous exuviæ are very numerous, and so well preserved, as to have the freshness of recent shells. With respect to *generic* character, there are few existing shellfish which are not represented

by types in the London clay; but in *specific* character there is a frequent difference. Of the extinct genera which are so common in the deeper seated strata, few specimens occur in this, showing the intermediate epoch of its formation. Thus though nautilites resembling those of the Indian seas are still common, ammonites and belemnites are so rare, as to render it doubtful if any be really buried in the clay. Ammonites and belemnites may occur superficially which have been detached and drifted from the inferior oolites. Echinites so common in the chalk, are seldom seen in this superior stratum.

M. Defrance has collected in the corresponding geological formation at Grignon, near Paris, 800 different species of shells, besides serpulæ, siliquaria, dentalia, and a few echinites and madrepores. It is probable that if an equally skilful and zealous conchologist were to explore the Hordwell cliff in Hampshire, he would find corresponding species, and numbers of shells. In the lower beds of the French *calcaire grossier* at Liancourt, Mr. Webster observed an exact accordance in organic remains with the beds of the London clay at Stubbington.

Zoophytes and encrinites are likewise very rare. Portions of wood occur, which are fibrous at one time and charred at others. These exhibit the perforations, and even contain the casts of an animal analogous to the *teredo navalis*, or borer, which now commits great havock on the planks of ships in tropical seas. In the heart of the nodules of argillaceous limestone, which resemble septaria, a wooden nucleus is frequently found. These masses

also contain shells, that possess their fresh pearly lustre.

The most curious vegetable remains of this formation, are those of fruit and ligneous seed-vessels found in vast profusion and variety in the Isle of Sheppey. Mr. Crowe of Faversham, has made a collection of seed vessels from this locality, amounting to no less than 700 different varieties, of which very few agree with any existing seed vessels known to botanists.

A few of the same vegetable remains have been found likewise on the opposite shore in Essex, as also at Kew. Among Mr. Crow's specimens are many which belong to tropical climates. Some are evidently a species of cocoa nut, and others are varieties of spices.

A fossilized nut of an extinct species of coco tree; from Sheppey.

"The evidence of a neighbouring region of dry land seems attested by these vegetable remains, (which from the state in which they are found can scarcely be supposed to have been drifted from any great distance,) as well as by the occurrence of the amphibia before mentioned. We can scarcely resist the temptation of asking, What was that ancient land? had any part of England then raised its head above the waves? Does it not sound extravagantly, even to inquire whether its oldest and highest mountain tracts then formed a groupe of spice islands frequented by the turtle and crocodile? Speculations like these, though unavoidably sug-

gested, almost give the features of romance to the sober walks of science."—*Conybeare, Geology of England*, p. 30.

Wherever the sea has broken up the solid clay, numbers of its imbedded fossils come into view; as in Harwich cliffs in Essex; in those on the north of the Isle of Sheppey; and especially those between Hordwell and Christchurch on the south-west of Hampshire.

This clay forms the upper stratum of the London chalk basin, except where it is covered with the sands of the upper marine formation, as on the surface of Highgate-hill, Bagshot, Frimby, Purbright heaths, &c.; or by alluvial and diluvial gravel, and loam. The London clay stratum constitutes a very considerable part of the soil of Suffolk, nearly the whole of Essex, including Hainault and Epping Forests, down to the sea, the entire surface of Middlesex, with portions of Surrey, Berkshire, and Kent. Here it is seen on the northern side of the Medway; it constitutes the Isle of Sheppey; the cliff from Whitstable to the Reculver north of Canterbury, and thence westward to Boughton Hill. It is also very extensive in the chalk basin of the Isle of Wight. The whole coast from Worthing in Sussex to Christchurch in Hampshire is formed of this clay bed. Thence it extends inland by Ringwood, Romsey, Fareham, to Worthing, composing the surface soil except in a few places where it is covered by sand or alluvium. In the Isle of Wight, it extends in a *dislocated upright position*, all along from Alum Bay on the west, to Whitecliffe Bay on the east. Its two planes therefore front to the south

and north. The former is faced up by the nearly vertical beds of the plastic clay formation, which had been uplifted with it; and the latter is covered above with nearly horizontal layers of the fresh-water, and upper marine formation.

The highest elevation of the London clay beds, is the summit of High Beech in Essex, 759 feet above the level of the sea. On the northern half of the Isle of Sheppey, the London clay is observed at 90 feet high, stretching 4 miles in length, and declining gradually towards the east and west. Whole acres of the cliffs are sometimes broken down at once into the sea. Since the days of Henry the Eighth, the sea has by this action, encroached about a mile on the north-west coast of the Isle of Thanet; the church of Reculver which has had its wall and half of its yard now washed away, having been in those times at the above distance. In thickness the London clay bed is very variable. At a spot, one mile east of London, it has been found only 77 feet thick; at Tottenham, 110; at White's Club-house, St. James's, 235; while in Portsmouth 266 feet were perforated without passing through the clay. It is said to have been dug into at lord Spencer's at Wimbledon in Surrey to the depth of 530 feet without getting through it. At High Beech in Essex, its thickness cannot be less than 700 feet. With the singular exception of the Isle of Wight, the beds of the London clay are nearly horizontal. Its mechanical disturbance is here demonstrable. Among the vertical strata of the *plastic* clay formation of this island, there is a thick layer of *rolled chalk flints,* standing also

upright, which must have been thrown into this position from the flat posture in which gravitation originally strewed them. The disturbing force seems to have operated with the greatest effect in a lateral direction. The central line or axis along which it has acted may be traced nearly east and west to the extent of no less than 60 miles, viz. from the eastern end of the Isle of Wight to Abbotsbury in Dorsetshire. The vertical chalk beds, which have also partaken in this great dislocation, terminate indeed at Whitenose, but a highly inclined saddle of the substrata may be traced in the prolongation of the same line.

The first section of this extraordinary stratum, in advancing westwards, is seen at Culver Cliffs, a magnificent range of precipices near the east end of the isle, forming a promontory which separates Whitecliff bay on the north-east, from Sandown bay on the the south-west. The superstrata of the plastic clay and sands may be observed at Whitecliff in an upright position, forming low cliffs. Immediately to the south, the chalky strata tower to a stupendous height, with an inclination to the horizon of about 70°. Southwards, round the cape, this angle falls to 50°. The direction of the dip is north-north-east. All the beds of chalk towards what had been their upper side, contain alternating strata of flint-nodules, the whole of which with the exception of a few detached ones in the body of the strata, are in a most extraordinary condition; broken in every direction into fragments varying from three inches diameter, to impalpable particles. Yet the flints so shivered, by some mysterious concussion,

retain their outward form and position in the bed. The chalky coating still invests them undisturbed. When this is removed, fine lines are perceived which correspond to the internal fractures, as we see in a piece of unannealed glass, cracked by a scratch. Like the glass, too, the flints fall asunder when moved. The fragments are all as sharp and irregular as possible, but devoid of crystalline arrangement.

The London clay is an extremely dense soil, rendered productive round the metropolis only by excessive working. It is almost impervious to water, and containing besides much saline matter, cannot be expected to give origin to good springs. But the alluvium above the clay, affords a very considerable supply of water. What rises from the sands of the plastic clay strata beneath, is limpid and soft, gushing up so suddenly after cutting through the London clay, that the welldigger is in danger of being drowned at the instant of its issue.

§ III. LOWER FRESHWATER FORMATION.

This is but a partial deposit occurring particularly at Headenhill, Isle of Wight, in a series of beds of sandy, calcareous, and argillaceous marls, mingled often with a little coaly matter. Some of these appear to consist almost wholly of the fragments of freshwater shells, many sufficiently entire to show their species.

Section of Binstead Quarries, illustrative of this formation.

On the summit lies,

	Feet.
1. Blue clay, containing many loose masses from the Upper freshwater formation of variable thickness.	
2. Limestone composed of coarse fragments of freshwater shells,	2
3. Do. in smaller fragments, ...	4

	Feet.
4. Limestone finer,	2
5. Do.	$1\frac{1}{2}$
6. Siliciferous limestone,	$1\frac{1}{2}$
7. White shell marl,	$0\frac{5}{6}$
8. Siliciferous limestone,	$0\frac{1}{2}$
9. Sand,	$0\frac{2}{3}$
10. Siliceous limestone rag,	$0\frac{1}{2}$
11. Sand,	50
12. Blue clay, depth unknown.	

The organic remains of the above beds are lymneus, planorbis, and cyclostoma, perhaps the helix, and a bivalve, resembling the fresh water muscle. No marine exuviæ have been detected in these beds. This formation at Headen hill is extremely irregular in its range, and cannot be continuously traced for more than a few hundred yards, so that it is to be seen only in apparently insulated masses, emerging from beneath the mouldering slope. The whole of the north end of the Isle of Wight has been referred to the fresh water formation, but the confusion of the strata is so great, that it is difficult to find any of them in their original seats. Hence fresh and salt water shells are intermixed on the west and north coasts, though now and then they occur in alternate layers. This formation may be traced to a considerable distance east of Ryde, perhaps as far as Nettlestone. Its greatest height is 90 feet; its greatest thickness 63. In the above section it is only 14.

§ IV. UPPER FRESH WATER FORMATION.

This lies above the preceding bed, separated from it by a 6-inch seam of sand. It is covered by alluvium, as on the summit of Headen hill. This

upper fresh water stratum is a yellowish white marl, containing a large proportion of calcareous matter. It is the best characterised bed of Headen hill, and contains crystalline veins of pure carbonate of lime, along with abundance of the same fresh water shells enumerated above, unmixed with any marine exuviæ. It extends to many parts north of the middle range of chalk hills. In the neighbourhood of Calbourne, and onward to Thorley, several quarries have been opened in it, which yield an excellent durable stone. This bed forms the upper part of Headen hill, 400 feet above the sea, and is 55 feet thick. Elsewhere it occupies low situations.

The occurrence in England of a distinctly marked fresh water formation was first observed by Mr. Webster, Sec. Geo. Soc., and it may, generally speaking, be considered as limited to a portion of the Isle of Wight. We should be careful, says the Rev. W. D. Conybeare, not to confound these fresh water strata, which from their alternation with the regular marine formations, clearly belong to a period anterior to that at which our continents finally passed into their present condition, with the occasional occurrence of fresh water shells in alluvial tracts, belonging possibly to a very recent date, and certainly to one less ancient than the above. Near Kew, in Surrey, land and river shells were found in sand and gravel overlying the remains of elephants, &c., and therefore certainly posterior to the catastrophe which inhumed these animals. Though many of the shells found on Headen hill, be thin and brittle, they are quite entire; whence, it is inferred, that the shellfish must have lived and

died on the spot, and that what is now considerably elevated must have been once the bottom of a fresh water lake, which was twice within the bosom of freshwater, and in the interval covered by salt water. The freshwater formation of England has none of the beds of gypsum, found in the French strata, replete with bones of extinct quadrupeds. The lower freshwater formation has been observed at Hordwell Cliff, Hampshire.—*Geol. Trans. 2d series*, Vols. I. & II.

§ V. UPPER MARINE FORMATION.

1. This is observed in three districts; that of Suffolk, where the deposit on the London clay appears as a sand or gravel enclosing shells of peculiar characters. This whole mass is called Crag.

2. The sandy beds of Bagshot, and the neighbouring heaths.

3. The marine stratum, alternating with those of freshwater in the Isle of Wight, which consists of a shelly marl. Many of the fossils belonging to the beds of the Suffolk crag, agree with those in the upper marine formation of the Paris basin. A few shells only, which may be placed among those which are supposed to be lost, or among those which are the inhabitants of the distant seas, are discoverable here; but the greater number do not seem to differ specifically from the recent shells of neighbouring seas. A peculiar terebratula has been described, as well as many other curious testaceous remains. This bed at Walton Nase, Essex, and on the cliffs on both sides of Harwich, is 30 feet thick. It furnishes a good soil. The gray weathers or Druid-

stones of Stonehenge belong to the siliceous sandstone of the Bagshot heath formation.

§ VI. SUMMARY RECAPITULATION.

Guided by the inductive spirit of English geology, we have traced in the preceding chapters, the successive ranges of mineral strata from their primitive bases up to the surface soil. The Alps, Scotland, and other mountainous regions, afford better fields for the study of granite, gneiss, and mica-slate; but in no country can the coal-measures, and the supermedial strata be examined with so much advantage as in England, in consequence chiefly of the numerous sections which have been accurately made, and faithfully recorded, without regard to any hypothesis.

1. We have seen the coal-measures, or their equivalent beds, surmounted by the conglomerate limestone, called the newer magnesian, to distinguish it from the magnesian lime occasionally subordinate to the carboniferous limestone. This conglomerate is the first flœtz limestone of continental writers. It is covered by the new red sandstone, or red marl rocks of England. Between the *first flœtz limestone* and coal-measures of the Germans, their first flœtz sandstone lies, called *rothe todte liegende*, or *red dead layer*, because it is barren of the metallic veins found in the lower beds.

2. Next comes the oolitic series of rocks, the limestone beds of which are generally characterised by the spherical form of their calcareous particles, hence called roestone, peastone, or eggstone, according to their size. Immediately on the *red*

ground, the *lias* rests, being a structure of argillaceous limestone beds, in thin slabs, separated by seams of clay. Over this formation, we have the lower system of oolites, including fuller's earth, and bastard freestone, which reposes on calcareous sand. We now come to the *great oolite*, the *Forest marble*, and the *Stonesfield slate*, which are surmounted by the *cornbrash*. It is in this valuable oolite, that the sphericity of the calcareous concretions becomes most remarkable. These beds are covered by the Oxford clay, which is roofed with the coral rag, a mixed formation of calcareous and siliceous beds. Next in the order of superposition appears the upper division of the oolitic series, distinguishable into its three strata of Kimmeridge clay, Portland oolite, and Purbeck argillaceous limestone. This very important series, the oolitic strata, seems to be very rare in Scotland, and to exist but imperfectly in two or three patches of lias in Ireland.

3, 4. In ascending from the oolitic series, we find beds of iron sand, clay, green sand, and chalk-marl, leading to the great chalk formation; strata to which I am not aware that Scotland possesses any analogues, except in two or three spots in the Hebrides and Sutherland. 5. The tertiary class of strata which repose upon the chalk, have been examined under the most favourable circumstances, and with commensurate skill in the Paris basin, by MM. Cuvier and Brogniart. A brief abstract of their elaborate memoir, will conclude our view of the stratiform masonry of our globe.

§ VII. ALTERNATE FRESH AND SALT WATER BEDS.

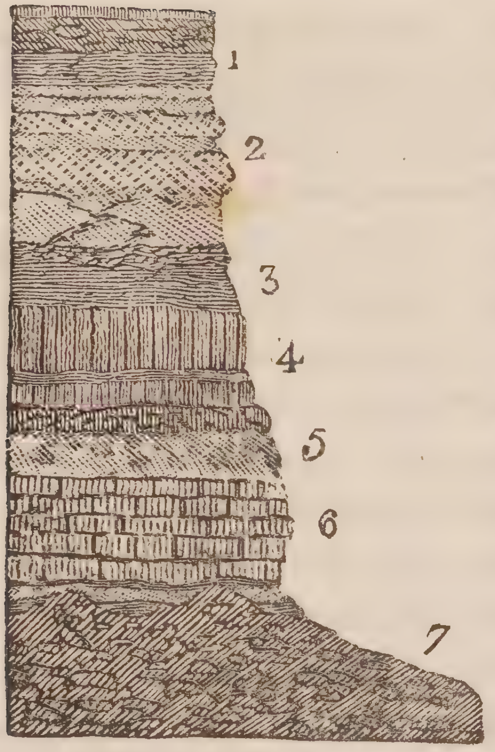
Of the Paris Basin.—The ground in which this capital lies, with the surrounding territory to a very considerable distance, presents a geological formation very remarkable for the diversity of its constituent strata, and the extraordinary relics of ancient organised beings which it has revealed. Its principal mass consists of myriads of marine shells, placed in regular alternate order with fresh water shells. Certain spaces are replete with skeletons of animals, unknown to the living world, even in generic affinity; while other bones, belonging to very considerable species, whose *congeners* are now found only in very distant countries, lie scattered about in the more superficial strata. In the forms of the capes and the directions of the principal hills, a marked character is impressed, of a great irruption of water having come from the south-east. We may hence infer that few localities are more capable of giving us information concerning the latest revolutions which completed the fabric of our globe.

The basin of the Seine is widely separated from that of the Loire, by a vast elevated plain, the greatest portion of which is commonly called the Beauce. The declivities of this extensive table-land are in general very steep, and all its naked escarpments, the sides of its valleys, and the wells which perforate the upper grounds, show that the physical constitution of the surface is the same throughout; consisting of a prodigious mass of fine sand, which covers the whole district, and invests

all the other strata of the slopes and lower plains. The materials which compose the basin of Paris, seem to have been deposited in a vast concavity, a species of gulf, lined throughout with chalk.

Enumeration of the different kinds of strata or formations, which constitute the geological district of Paris.

Formations.		*Sub-formations, and principal beds composing them.*
I. Ancient marine formation,	1.	Chalk.
II. First freshwater formation,	2.	Plastic clay. Lignites. First Sandstone.
III. First marine formation,	3.	Coarse limestone, and the sandstone which it frequently contains.
IV. Second freshwater formation,	4.	Siliceous limestone.
	5.	Gypsum with bones. Freshwater marls.
V. Second marine formation,	6.	Marine gypsum marls.
	7.	Third sandstone and upper marine sand. Limestone & upper marine marls.
VI. Third and last freshwater formation,	8.	Millstones, not shelly. Shelly-millstones. Upper freshwater marls.
VII. Diluvial and alluvial formations,		Rolled pebbles and ancient pudding-stones. Alluvial loam of ancient and modern date. Black clay-marls and peat-moss.



The figure on the margin represents the successive strata of the Paris basin, numbered from the surface downwards; or in the inverse order of the preceding table.

1. Upper freshwater marls and millstones. 2. Marine marls. 3, 4. Second freshwater formation; and gypsum with bones. 5. First marine formation after the chalk. 6. Lowest or oldest freshwater formation. 7. Chalk with flints.

1. *Chalk.*—The regular beds of black flints which exist in such abundance in the chalk, show that it has been the result of a tranquil deposit under the ocean.

The chalk masses of the environs of Paris are apparently intersected by nearly vertical fissures, sometimes very narrow, although they extend to very great distances; at others nearly two feet wide. The sides of these rents seem as if embossed, but the convexities and concavities do not regularly correspond with each other. The faces of the fissures look like surfaces which have been worn down, and polished by the waters. In the parts where the rents are so narrow as to allow the two walls to come nearly in contact, there are round vertical holes, irregularly placed, opening into the upper and wider portion of the cleft. Besides being embossed, the walls are pitted, as if exposed to a pelting rain. The flints which project in relief on

the sides of the clefts, have their upper faces covered with crystals of carbonate or sulphate of lime, but their under surfaces are bare.

These effects cannot be ascribed to the action of *existing waters*, because; 1. The masses of chalk in which they occur, are much above the highest level of the waters of the Seine, and all its affluent streams; 2. The superior strata, and the adjoining hills have too little mass, or elevation to supply currents of water capable of producing these effects; Lastly, water and its springs are so rare in the chalk, that the quarriers at Meudon have been obliged to dig a deep well, in which the water stands 70 feet below the lower level of the quarries. The only metal found in the chalk formation of Paris, is iron in the state of a sulphuret, or globular pyrites, either disseminated, or incrusting the organic *debris*.

The animal exuviæ give geognostic characters to the chalk, which are clear, essential, and decided. They are very unequally distributed through its mass. Not only are they almost all different from those which occur in the other formations, and particularly in the more recent ones; but they also present notable differences in species and even genera, according as they belong to the upper or lower portions of the chalk. This important consideration leads to the recognition of three members in the chalk formation, distinct in the central portion, but on their confines passing insensibly into each other. These three members which thus differ not only in geognostic position, but also in mineralogical character, are

1. *The white chalk* or middle portion; 2. The chalk called *tufau* in Touraine, the upper part of which is generally grayish and sandy, containing usually hornstones instead of flints; 3. The chloritic chalk, called by Cuvier *chalky glauconie* (green sand of the English). It is grayish, friable, and all over besprinkled with green particles which closely resemble chlorite. The greenish or reddish nodules from an analysis by M. Berthier seem to consist chiefly of phosphate of lime and iron.

Analysis of the grains of the green sand from Havre, by M. Berthier.

Silica,	50
Protoxide of iron,	21
Alumina,	7
Potash,	10
Water,	11
	99

Analysis of the greenish nodules (glauconie crayeuse).

Phosphate of lime,	57
Carbonate of lime,	7
Carbonate of magnesia,	2
Silicated iron and alumina,	25
Water and bituminous matter,	7
	98

The *white chalk* alone is found in the vicinity of Paris. This circumstance limits considerably the number of organised exuviæ exhibited there, for it is in the *tufau and chloritous chalk* that the fossil shells are most abundant. See Plate V.

None of the chalk shells are found in the coarse limestone (*calcaire grossier*) above it. These two formations are, therefore, perfectly distinct, nor is there any trace of an insensible transition between them, either in the Paris district or probably elsewhere. On the other hand, no such decided dif-

ference is observable between the chalk and its subjacent compact limestone. The chalk of other countries, includes species of shells not hitherto observed at Paris, but which are found in the oolitic limestones beneath it. These facts prove that the chalk is not, as many have supposed, of modern origin. We shall find that it has been succeeded by four or five very distinct formations, which indicate a long space of time, and great revolutions, between the period of its deposition, and of those strata from which the surface of our continent has derived the figure which it actually possesses. With the exception of the *trochus*, there has not been found in the Paris chalk any univalve shell with simple and regular spires. Thus there is no cerite, no fusus, &c. This fact is the more remarkable, as we find a few yards above the chalk, in strata equally calcareous, shells in great abundance of a different structure.

The chalk forms the bottom of the basin or gulf, within which are deposited the several formations of the Paris district. Ere this antique chalk floor was covered by these mineral strata, its surface must have exhibited hollows and prominences in the form of valleys, hills, and terraces. These inequalities are still indicated by the islets and promontories of chalk which rise up through the new formations in certain points. Hence the excavations made in these upper beds reach the chalk at very variable depths. Nor have the inequalities any relation with those of the actual surface of the land.

2. *First freshwater formation, plastic clay, lignite, sandstone.*—Almost the whole surface of the chalk mass is covered with a bed of clay, possessing very remarkable general characters, amid specific differences at different points. This clay called plastic, because it readily takes and keeps the forms impressed on it, is unctuous, tenacious, and generally composed of about 30 alumina, 60 silica, and 10 water in the hundred parts. It is rarely impregnated with either lime or iron, and makes no effervescence with acids. It is of a fine white aspect at Moret; gray at Montereau; yellow at Abondant; pure slate-gray, or slate-gray mixed with red to the south of Paris from Gentilly to Meudon.

This bed varies in thickness from 50 feet in some places, down to a seam of a few inches in others. Two beds of clay are often met with; an upper one, which the workmen call *fausses glaises* (false potter's-earth) is sandy, blackish, and encloses occasionally organic remains; and an under one separated from the former by a bed of sand. The lower stratum which forms the proper plastic clay, is destitute of organic debris; but the upper one is sometimes very rich in fossils, which give it a peculiar character. To this bed and consequently to the plastic clay formation, of which it constitutes a member, belong the sands, and lignites, yellow amber, and numerous fossil shells, some obviously marine, and others natives of freshwater.

The lignite or fossil bituminous wood (braunkohle of the German mineralogists), sometimes

appears in carbonaceous traces of the stem, branches, or leaves, and sometimes as buried trees. This evidence of its origin gradually vanishes, and the carbonaceous matter assumes the aspect of regularly stratified beds, or layers of an earthy appearance, called pyritous ashes, earth-coal, or marine peat; sometimes it constitutes compact masses of a pretty pure black, of a dense texture susceptible of polish, divided by fissures into rectangular masses, when it is termed brown coal, jet, and even coal. The lignite under these two forms, is either in thin unconnected seams, or in thick beds of great extent; but in both cases, though the ligneous texture should be entirely effaced, some portions of vegetables tolerably well preserved, such as stems, leaves, fruits, are found, which prove that they are derived rather from trees than herbaceous plants, most frequently dicotyledinous, almost always of the family of palms, and never, it is said, of the fern tribe. This circumstance is one of their most remarkable characters, and establishes a very obvious distinction between the ancient and genuine pit-coals, and these deposits of more modern date, to which the name of pit-coal is improperly applied.

The fossil shells, which very commonly accompany, and sometimes in prodigious quantity, this upper bed of the plastic clay formation, or the carbonaceous marl, belong to genera, and perhaps species which live in very different elements, some being marine, and others freshwater shells. These two lie sometimes in thin layers, which touch each other, and though together not a foot thick, yet they are quite distinct. Most commonly, however,

as in the whole of the *Soissonois* district, these shells are mixed, but this happens only at the line of contact of the two beds; so that the fresh water shells belong to the lignite stratum, that vast deposit of vegetables which assuredly did not live in the waters of the sea, but grew on the surface of the earth, when that consisted solely of chalk, and was covered with forests, lakes, or marshy pools; whilst the marine shells were bred in the marine deposit, which covers with numerous and massive strata the above argillo-carbonaceous formation.

The following list of the *fresh water shells* has been given by M. de Ferussac :—Planorbis rotundatus, incertus, punctum, Prevostinus; physa antiqua; limneus longiscutus; paludina virgula, indistincta, unicolor, Desmaresti, conica, ambigua; melania triticea; melanopsis buccinoïdea, costata; nerita globulus, pisiformis, sobrina; cyrena antiqua, tellenoides, cuneiformis.

Marine-shells from the intermixture of the superior beds, contain the following: ceritium; ceritium funatum, melanoides; ampullaria depressa; ostrea bellovaca, incerta.

The two mineral formations now described must have been produced under entirely different circumstances, since they differ in their chemical nature, in their mode of stratification, and especially in their fossil inmates; so that there is every reason to conclude that the plastic clay belongs to a formation distinct not only from the chalk, but likewise from the superior coarse limestone; since the organic remains appropriate to it, are land or fresh water shells, while all those of that limestone belong to the sea.

3. *Of the coarse limestone formation, (calcaire grossier), and its sea-shell sandstones.*—This limestone does not always rest immediately on the plastic

clay; but is sometimes separated by a bed of sand, sometimes aggregated into freestone. The calcareous formation itself is composed of alternate beds of coarse limestone more or less hard; of argillaceous marl often in very thin layers; and of calcareous marl. It must not however be supposed that these different courses of masonry are placed fortuitously, and without rule, for they always maintain the same order of superposition, over the whole extent of the vast basin. Several seams may be sometimes wanting or very thin; but what is inferior in one district, never becomes superior in another.

This constancy in the order of superposition of the thinnest strata, and over an extent of nearly 80 miles, is certainly one of the most remarkable facts disclosed by the researches of MM. Cuvier and Brogniart. The fossil shells furnish the means of recognising amidst so many calcareous layers, any particular one observed in any district however remote. This criterion has never deceived the eminent French naturalists. It is not however to be supposed that the difference between one bed and another is so remarkable, as that between the chalk and the coarse limestone. But the fossils characteristic of one bed become less numerous in the bed above, and disappear entirely in the others, or are gradually replaced by new fossils which had not till then made their appearance.

The first and lowest beds of the calcareous formation are the best characterised; they are very sandy, sometimes more so than they are calcareous. When solid, they are apt to decompose in the air and fall to powder; so that the stone can be

employed only in very peculiar circumstances. This stratum contains almost always some green earth in powder or grains; which by the analysis of M. Berthier appears to be a silicate of iron. Here is found also a prodigious quantity of fossil shells, the greater part of which differ more from our living species, than the shells of the superior strata do. They are entire, well preserved; and may be easily detached from their rock, retaining in many specimens their pearly lustre. The middle beds also include a great many species of shells; among which are brown impressions of leaves and stems of plants, mixed with cerites, thick *ampullaires* and other sea-shells. The plants cannot be referred to any marine vegetables. The third or superior system of strata includes fewer shells than the two preceding. The lower seams of it are hard, and are used in building. Above the last beds of the coarse limestone, hard calcareous marls appear, divisible into blocks with their surfaces covered with a yellow varnish, and black dendritic (tree-like) impressions.

It appears, therefore, 1. that the fossils of the coarse limestone have been slowly deposited in a tranquil sea, and now lie in regular beds; that they are not mixed; and that the greater portion are in a state of perfect preservation, however delicate their texture may be, since even the points of the spinous shells are very often entire; 2. that these fossils are entirely different from those of the chalk; 3. that in proportion as the beds of this formation were deposited, the species changed, and several of them disappeared, while new ones made their appear-

ance, circumstances which indicate a great many generations of marine animals; lastly, that the number of species of shells always went on diminishing in that region, till the period when they entirely vanished. The waters which deposited these beds, either contained no longer any shell-fish, or lost the faculty of preserving them.

Certainly things happened in those primeval seas far otherwise from what occurs in our present ocean. In the latter, solid shell-limestone rocks now rise only in tropical climates. The species of shells are not found to change on the same banks and coasts. Ever since oysters have been fished on the coast of Cancale; and mother of pearl *aviculæ* in the Persian Gulf, it has not been observed that one order of shells has given place to another.

4. *Siliceous limestone.*—This formation consists of distinct courses, of a limestone sometimes tender and white, sometimes gray and compact, having a very fine grain, and penetrated with silica, filtered through on every point. It is frequently cavernous. These cavities are often pretty large, irregular, and communicate in every direction; they are occasionally cylindrical, but sinuous (winding), and though still irregular, they preserve with one another an appearance of parallelism. The silex by filtering into these cavities, has studded their sides with mammelated stalactites of various hues, or with pyramidal quartz crystals, short and almost without a prism, but distinct and pellucid. This disposition is very

remarkable at Champigny. The compact limestone, thus penetrated with silex, affords by burning, lime of very good quality. We may consider the siliceous limestone, as terminating on one hand the marine formation, and forming on the other, the lower portion of the middle freshwater beds. Hence this rock includes sometimes, in its lower ranges, sea-shells analogous to those of the coarse limestone, mingled with freshwater shells, thus constituting the passing link between the two formations; and the freshwater shells of its upper courses, are the same as those of the middle freshwater limestone. The compact and hard, but easily broken, yellowish limestone, called *clicart* by the workmen, should be referred to the same locality. In this formation, one kind of the stones well known under the name of mill or buhr stones occurs. These seem to be the siliceous skeleton, of a siliceous limestone. They must not be confounded, however, with the millstones to be described under the eighth head.

5, 6. *Gypsum, the second freshwater formation, and marine marls.*—These strata afford one of the clearest examples of what is to be understood by a formation in Geology; differing widely from each other in their chemical nature, yet evidently deposited at the same time. This formation which is called gypseous, is not composed solely of gypsum, for it consists of alternate beds of gypsum, argillaceous marl, and limestone, in an order of superposition always the same, over the great gypseous field studied by MM. Cuvier and Brogniart, from Meaux to Triel and Grisy, through

a length of more than 20 leagues. Some of the beds are wanting in a few districts, but the remaining ones are always in the same respective positions.

The gypseous course is placed immediately above the marine limestone, a superposition of which it is not possible to doubt. The hills or mounds of gypsum have a peculiar aspect by which they may be recognised at a distance. As they always lie over the limestone, they form as it were second hills of a distinctly oblong or conical shape, situated on the more extended lower elevations.

Both on Montmartre, and the hills which seem to rise in its suite, two formations of gypsum may be observed. The lower is composed of alternate beds of little thickness, consisting of gypsum often crystalline, solid lime-marls, and clay-marls distinctly foliated. It is in the former, that the large crystals of lenticular yellowish gypsum occur, and in the latter the menilite silex. The lower portions of this mass would seem to have been deposited, at one time naked, on the sea-shell calcareous sand, in which case they include marine shells, and at another, on a bottom of white marl, containing a great many freshwater shells, which had previously covered the marine stratum. This second circumstance seems proved by two observations made, the one at Belleville by M. Hericart de Thury, and the other by M. Cuvier under the street of Rochechouart. In digging wells at these two places, the last beds of the lower mass were perforated, and there was found in the under portions of this mass, a great bed of the white freshwater marl above mentioned.

Below this bed, occur either the first courses of the marine limestone, or the calcareo-siliceous lacustrine formation.

The superficial mass which the workmen call the *first*, is in every respect the most remarkable, and important. It is besides much larger than the others; possessing in certain places a thickness of 65 feet, and is uniform throughout, with the exception of a few marly beds. In some places, as at Dammartin, near Montmorency, it lies almost immediately below the vegetable mould.

The lower beds of gypsum of this first mass, include silex, which seems to have flowed into the gypseous matter, and also to be penetrated with it. The intermediate beds naturally split into thick prisms, with several faces, which are called *hauts piliers*, (high pillars); and the uppermost ranges called *chiens* are penetrated with marl. They alternate with marl strata and are not very massive. These are commonly five in number, and spread over a great extent.

But these facts are not the most important. The fossils which this mass includes, and those which its marls cover, suggest observations of far higher interest.

It is in this *first* mass that the quarriers find almost every day, skeletons and scattered bones of a multitude of unknown quadrupeds, along with the bones of birds, crocodiles, the trionyx tortoise, land and freshwater tortoises, and several kinds of fish, most of which belong to freshwater genera.

But what is no less remarkable, and leads to the same conclusion, is that some freshwater shells are

also found there. They are doubtless of very rare occurrence; but a single one would suffice, when unaccompanied with sea shells, to demonstrate the truth of the opinion which Lamanon and some other naturalists broached long ago, that the gypsums of Montmartre, and of the other hills of the Paris basin, had been crystallized in freshwater lakes. We shall presently adduce new facts confirmatory of this judgment.

The superior gypsum is perfectly characterised by the presence of the skeletons and bones of mammifera, which enable us to recognise it, when it occurs insulated. They have never been observed in the inferior masses.

Above the gypsum, are placed thick beds of marl, sometimes calcareous, and at others argillaceous. In the lower courses of these beds, and in a white and friable lime marl, there have been met with at different times, palm-tree trunks petrified with silex. They were recumbent in posture, and of considerable dimensions. In the same system of beds, there occur in almost all the quarries of the Chaumond mound, and even in the quarries to the east of Montmartre, shells of the genera *lymnea* and *planorbis*, hardly different from those which now live in our marshes. These fossils prove that the marls are a freshwater formation, like the gypsums placed below them.

In ascending, we encounter a bed of foliated yellowish marl about a yard thick. This forms the limit of the freshwater formation. All the shells that have been observed higher up, are marine.

Immediately over this marl, there is a large and

constant bed of greenish clay marl, which may be recognised at a distance by its thickness, its colour, and its continuity. It serves as a guide for finding the *cytherea* shells, which lie just below it. The four or five beds of marl that succeed the green one, are of little thickness, and like it contain no fossils. But these beds are immediately surmounted by one of yellow clay marl replete with sea shells, of species belonging to the genera *cerites*, *trochus*, *mactres*, *venus*, *cardium*, &c. Fragments of the palate of a ray, and portions of the spines of the tail of a ray, were also found in this locality.

Almost all the marl beds which succeed the last, present fossil sea-shells, but only of the bivalve class, and the latter strata, or those immediately below the argillaceous sand, include two distinct beds of oysters. The first and lowest is composed of very thick large oysters; some of them nearly 4 inches long. A layer of whitish marl without shells occurs next, then a second very thick stratum of oysters subdivided into several seams. The oysters are brown, and much smaller, as well as thinner than the preceding. The above oyster beds are almost uniformly present; nor have they been twice missed in the numerous hills examined by MM. Cuvier and Brogniart, so that it seems to be nearly certain that they lived in the place where they now lie; for they are attached to each other, as in the sea, the most of them are quite entire, and when carefully extracted, often retain both their valves. Lastly, M. Defrance has found near Roquencourt, as high as the marine gypseous marls, rounded pieces of the shell marl limestone, pierced with *pholades* (stone

borers), and still bearing the oysters that were attached to them.

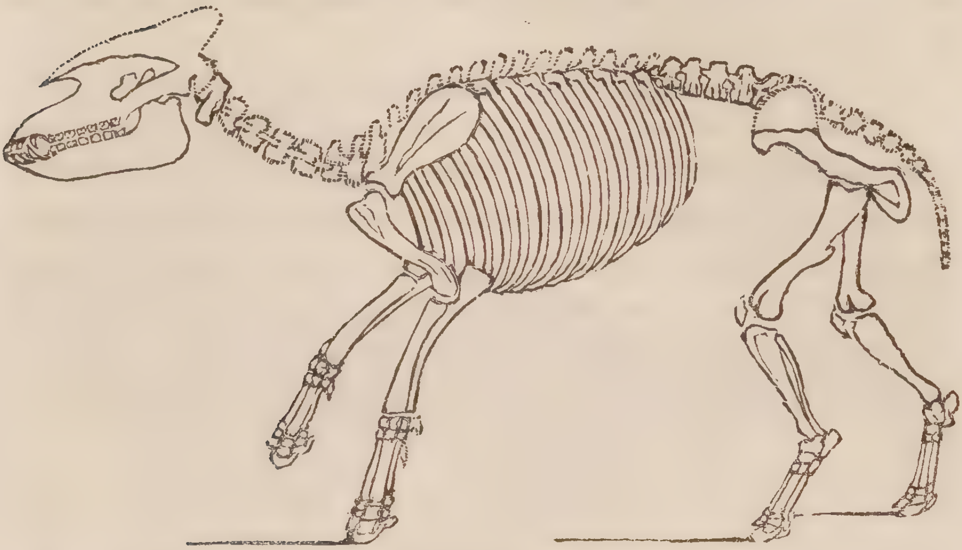
The fossils of the gypsum and marine marls which cover it, are ;

1. *In the gypseous mass ;* the palæotheriums, the anoplotheriums, the carnivorous and other mammiferous animals; birds of 3 or 4 species; a trionyx and other reptiles; a crocodile; fish, 3 or 4 species; and of the mollusca tribe, a *cyclotomia mumia.*
2. *In the superior white marls.* Palms, or other endogenites plants; remains of fish; *limnea* and *planorbis* freshwater shells.
3. *In the marine formation;* inner and outer casts of shells, the substance being generally wasted away; *spirorbes;* fish bone; *cerithium plicatum.*
4. *Green marls.* No fossils.
5. Yellow marls. Spines and palates of the ray; ampullaria patula? cerithium plicatum, cinctum; cytherea elegans; cardium obliquum; nucula margaritacea.
6. *Calcareous marls.* Ostrea hippopus, pseudochama, longirostris, canalis, cochlearia, cyathula, spatulata, linguatula; balani; crabs' claws.

The gypsum formation of the Paris basin cannot be referred to any of the formations described by Werner or his disciples.

Having eliminated by a long and laborious analysis, the separate pieces of the skeletons of unknown animals, found in this bed of the Paris basin; and assigned them their respective places in the system agreeably to the laws of organic being, M. Cuvier commenced their synthesis, collating and combining the bones, so as to represent, not the whole carcass indeed, but the frame-work of the animal.

The *Palæotherium minus* had furnished the most complete assortment of bones; with it, therefore, he began, proceeding afterwards to the Palæotherium magnum, next to the Palæotherium crassum, and lastly to the medium. Of his other species, nothing but fragments have been hitherto found.



The skeleton of the palæotherium minus occurred in a complete state at Pantin, near Montmartre, imbedded in gypsum. The wood-cut represents the palæotherium magnum restored, from its scattered bones. Its height was four feet and a half, about the size of the rhinoceros of Java. Lower than a great horse, it was also thicker, with a head more massive, shorter and stronger limbs. An almost entire skull of this animal was eventually found by M. Cuvier, which he regards with justice as one of the most interesting relics of the ancient world, since it enables him to confirm all his previous conjectures about its organization and habits. This skull equals in size that of the largest horses. The external opening of the nostrils was oblique and very long; surrounded by three pairs of bones, the intermaxillary, the maxillary, and the nasal; the last, instead of uniting with those of the muzzle, slope obliquely over the nasal orifice. Now, there are only three genera of known animals which have three pairs of bones in the external nostrils; these are the rhinoceros, the elephant, and the tapir; and the last two alone have the proper bones of the nose, thin and short as in this ancient animal. In the rhinoceros, on the contrary, these bones are as long as the snout, and of extraordinary thickness, on account of the horn which they have to support.

The horse resembles them in the obliquity of the opening, and in the inclined direction of the points of its proper nose bones, or in other words, by the large notch placed under them on either side; but its intermaxillary bones extend sufficiently to the sides

of the bones of the nostrils to reach these nose bones, and be articulated with them.

From these analogies in the osseous frame, we may justly infer a similarity, in the soft parts attached to it. The elephants and tapirs have a proboscis, and the rhinoceroses possess in their lip, and the horses in the whole extremity of the snout, a mobility which depends on an organization, closely resembling that of the tapir. As the palæotherium had no intermaxillary bones like those of the elephant, it could not have a similar proboscis. From a comparison of the other three genera, it must have been formed as this

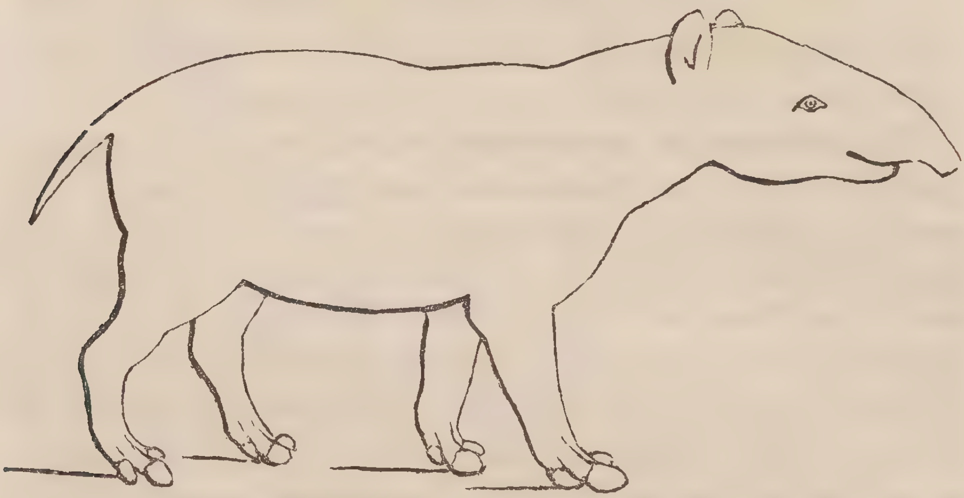


figure represents it; being intermediate between a tapir and a horse. But as its orbit was small, so also must its eye have been, whence it would have the stupid aspect of the hog. The temporal fosse was large and deep, indicating great powers of mastication.

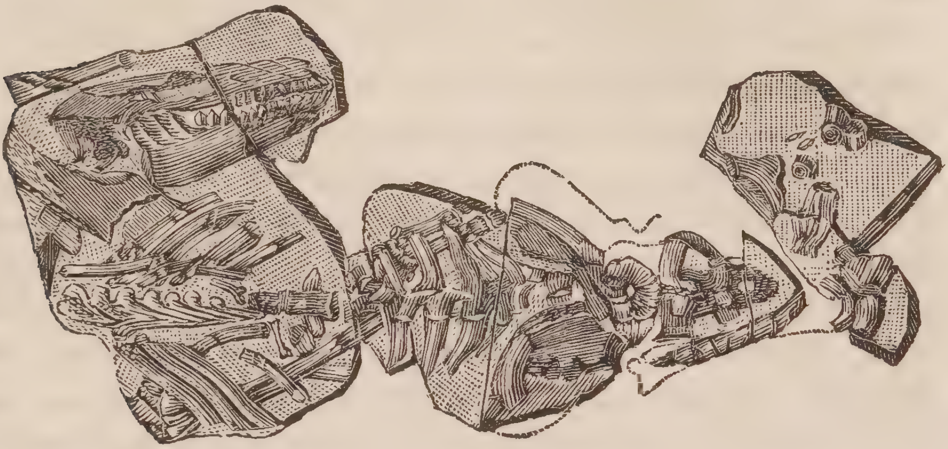
Of the small palæotherium (minus), M. Cuvier says, could we restore this animal to life, as easily as we have rejoined its bones, we should have before us a tapir a little longer than a roe-buck, with light and slender limbs. Its height in the middle was only 18 inches.

Seven species of palæotheriums* are enumerated, all dug out of the Parisian plaster beds.

The *magnum* had the size of a horse, the *medium,* that of a small hog, with long narrow feet; the *crassum*, same size, but with broad, shorter feet; the *latum*, same size, with short, squat feet; *curtum*, size of a sheep, spreading, very short feet; *minus*, rather

* Palæotherium; ancient wild beast.

smaller, narrow feet and side toes smaller; *minimum*, size of a hare, feet narrow.



To the other great genus of animals discovered by M. Cuvier in the Paris gypsum, the name Anoplotherium (unarmed wild beast) has been given, on account of the shortness of its canine teeth. In the fossil figured above, a specimen in such preservation was fortunately found, as explained the structure of the head, and greater part of the body. It shows the nasal and intermaxillary bones entire; the position of the intermaxillary suture, and of the suborbital hole; the zygomatic arch in perfect preservation, as well as the mastoid process; and the rising branch of the lower jaw, forced a little behind its true position. The specimen shows also the contour in profile of the posterior part of the skull. The animal approached to the Ruminant class. The most remarkable circumstance in this creature, is the enormous length and strength of its tail. Ten vertebræ belonging to it, and jointed together in another specimen, are not the only bones of which it was composed. M. Cuvier concludes that it must have consisted at least of 22 vertebræ, equalling, if not exceeding, the length of the body. No known quadruped has a tail of such size, excepting the kanguroo: and this is therefore another character to add to all the others which make the anoplotherium one of the most extraordinary beings of that ancient world, whose relics we now survey. Such immense tail-bones must have had proportionate muscles to move them; of which more than conjectures exist with respect to the anoplotherium. Their tendons, in part apparently ossified, have left on the stone, traces which lead us to judge that the thickness of the tail was as enormous as its length. We need not be

surprised at these traces, since the cartilages of the ribs have also left very evident prints. The specimen represented in our figure was dug out of the quarries at Antony near Paris, 100 feet beneath the surface. The animal seems to have sunk down into the yet unindurated plaster, lying on its belly in a horizontal position, with its head only deranged and thrown to one side, and its ribs broken and crushed together, as well as its other bones, by the weight of the superincumbent strata afterwards deposited. All the dorsal, lumbar, and sacral vertebræ remained in their places, preserving their natural connexions with each other, and with the pelvis. The height of the *Anoplotherium commune*, at the saddle, might be about three feet and a few inches. It must have derived from its tail somewhat of the look of an otter, and was probably accustomed like this animal to live in waters and marshy grounds; but not for the purpose of fishing; for like the water-rat, the hippopotamus, and the whole family of wild boars and rhinoceroses, the anoplotherium was herbivorous; roaming in quest of the succulent roots and stems of aquatic plants. From its swimming and diving apparatus, it must have had glossy hair like the otter; and perhaps its skin was even half naked like that of its kindred pachydermata. Its entire length, including the tail, was at least eight feet; and about five feet in the body, which is the length of the body of an ass of middle size; but the latter animal stands higher.

The *Anoplotherium gracile* was about 2 feet high at the saddle, nearly the height of the chamois, though its skull and other bones were not so thick; but this proceeded from the extreme slenderness of its limbs. While the *Anoplotherium commune* had a sluggish, and awkward pace, when it walked on the ground, the *gracile* was nimble and graceful; light as the gazelle or chamois, it would seem to fly round the marshes and the tanks, in which the former species swam about; it would browse on the aromatic herbs of the dry pastures, or nip the buds off the trees. Its speed was undoubtedly not encumbered with a long tail; but like all the fleet *herbivora*, it was probably a timid animal with large moveable ears, such as those of deer, to warn it of danger. Its body would also be clothed with short hair, so that only its colour is wanting to enable us to paint it as it formerly enlivened the country of its sepulture.

The *Anoplotherium leporinum* was the antediluvian hare of the same regions.

7. *The superior sandstones and marine sands.*—This formation is composed of siliceous sand and sandstone, in beds frequently of great thickness and extent, but with the two surfaces seldom parallel. Both of them, and especially the upper, often present irregular prominences and hollows, of a rounded shape, which scarcely ever correspond; whence their very variable and unequal depth. The inferior portion of the beds, consists of a very pure sand quite destitute of fossils; the superior affords nodules of iron-ore disposed in horizontal layers. This lower mass of the third sandstone deposit, is in many places terminated by a rock sandstone, limestone, or siliceous limestone, stored with sea shells, constituting a marked second marine formation above the chalk. It varies in colour, solidity, and even composition; and is evidently superior not only to the gypsum, but also to the extensive and very massive beds of sandstone, and sand without shells. There is therefore in the environs of Paris, three kinds of sandstone, sometimes very like each other in their mineralogical characters, but very different in position, and geological nature. On observing this last marine formation, placed in a position so different from the others, one cannot help reflecting on the singular circumstances which must have presided at the formation of the beds above described.

8. *The third freshwater formation including the marls and the millstones.*—This formation is distinguished from the two preceding by its position, and by some geognostic characters, which however are not sufficient of themselves, to designate it

with certainty, when it stands insulated from the rest. But its position in the vicinity of Paris, so perfectly distinct from that of the second fresh-water strata, leaves no doubt as to the difference between these two beds, separated as they are by a marine formation.

This upper lacustrine, or fresh water formation, is composed in different districts of different rocks. In the plain of La Trappe, it consists of white, friable, or at least tender calcareous marls; in the environs of Epernon, of translucid, light-gray, or brown horn-stones; in the mountain of Triel, Montreuil, &c., of opaque, white, or rose coloured jaspery flints; and on the plains of Meudon, Montmorency, Sanois, la Ferte-sons-Jonarre, &c., of porous or compact mill or buhr stones, reddish, grayish, or whitish in colour, sometimes without shells, sometimes replete with *limnei*, *planorbes*, *potamides*, *helices*, *gyrogonites*, silicified woods, and other organic remains, which must have lived in the fresh waters, or on the surface of the soil.

The millstones rest immediately on the sands, which contain the sandstones. That formation consists of a ferro-argillaceous sand, greenish, reddish, or even whitish, clay marl, and millstones properly so called. These three substances do not seem to follow any fixed order in their superposition; the millstone is sometimes above, sometimes below, and sometimes in the middle; and the same thing may be said of the sand or clay marl. The buhr-stones are very rarely in continuous beds, but rather in angular pieces, as if resulting from thin beds, broken and enveloped in the clay marl, and in the iron-clay sand. The millstone is well known to be a silex, riddled throughout with a multitude of irregular cavities, garnished with siliceous network, disposed almost like the reticular tissue of bones, and daubed over with a red ochrey varnish. These cavities are often filled with clay-marl, or clayey sand. They do not communicate with each other.

Another geological character of the proper buhr stones, namely of such as by the continuity of their mass are fittest for making flour millstones, is the absence of every organic body animal or vegetable, marine or fresh water. Sometimes these stones are covered

only with vegetable mould, but often also we find above it, some compact buhr stones, flints, or marls, including fresh water shells or other organic remains (not marine), or diluvial rolled pebbles lying in a coarse grained sand. The most common associate of the millstones, is the freshwater limestone, nearly pure; the mixture of limestone and silex is next in abundance, and the great masses of freshwater siliceous stones are the rarest. Whether the limestone be marly or compact, it shows very often cylindrical cavities, irregular, and nearly parallel though sinuous. This freshwater limestone however hard when taken out of the quarry, sometimes falls down into a coarse powder, by the action of the weather; on which account it is chiefly used as a manure.

But what characterises essentially this formation, is the presence of freshwater and land shells, almost all similar in genera to those now found in the French marshes or pools; such as *limnei, planorbes, potamides, turbinated* shells akin to the *cerites, cyclostomes, helices,* &c. We also find those small round grooved bodies, which seem to be the grains of a species of *chara.* (See the account of Loch Bakie, next section). It is remarkable that no bivalve shells occur in this formation, at least in the neighbourhood of Paris.

The following testaceous mollusca occur:

Cyclostoma elegans antiquum; potamides Lamarkii; planorbis rotundatus, cornu, Prevostinus; limneus corneus, fabulum, ventricosus inflatus; bulimus pygmeus, terebra; pupa Defrancii; helix Lemani, Desmarestina.

There are also several vegetables of indeterminate genera. Among the determinate, are *chara medicaginula,* helicteres; and nymphæa arethusæ (rhizoma, *a subterranean stem*).

This freshwater formation is widely spread, not only over the environs of Paris, even thirty leagues to the south, but it is found in other districts of France. It has been recognised by M. Brogniart in Cantal, and in the department of Puy-de-Dome; and it occurs in many other places, but constantly with the same characters. It is matter of surprise,

therefore, that it has hitherto been so little noticed by naturalists. (*See next Section.*)

The great extent of this formation in the environs of Paris, and its presence in many other places, must make us admit the existence of great bodies of fresh water in the ancient state of the earth. Although we had no other examples of such extensive inland lakes, it would not seem more difficult to believe that they must have existed, than to admit the presence of the sea over the ground which constitutes our actual continents, along with so many other geological phenomena, no less inexplicable, though they cannot be contested.

But in the case under consideration, we have still before us in the present state of the earth, examples of freshwater lakes, almost equal in length to France from north to south, and of immense breadth. We need merely look to a map of North America to be struck with the vast magnitude of lakes Superior, Michigan, Huron, Erie and Ontario.

And in the operations of the petrifying calcareous waters now forming the *travertino* of Italy, we have an example of a great freshwater formation of rocky strata, as *dense* as any in the limestone beds of Paris.

On reconsidering these beds from the chalk upwards, we conceive first of all a sea depositing on its bottom an immense mass of chalk, and mollusca of peculiar species. This precipitation of the chalk, and of its attendant shells suddenly stops; the sea retires, waters of another kind, very probably analogous to that of our freshwater lakes, succeed, and

all the hollows of the marine formation are filled up with clays, debris of land vegetables, and of freshwater shells. But soon another sea, producing new inhabitants, nourishing a prodigious quantity of testaceous *mollusca*, entirely different from those of the chalk, returns and covers the clay, its lignites, and their shells, to deposit on that basis, thick beds, composed in a great degree of the shelly-coverings of these new *mollusca*. By degrees, this production of shells diminishes, and also comes to an end; the sea withdraws, and the soil is again covered with lakes of freshwater. Alternate strata are formed of gypsum and marl, which envelope both the debris of the animals bred in the lakes, and the bones of those which lived on their banks. The sea comes back once more; it breeds at first some species of bivalve and turbinated shellfish, which disappear, and are replaced by oysters. An interval of time now elapses during which a great mass of sand is deposited. We are led to believe that no organized bodies lived at that period in this sea, or that their exuviæ have been completely destroyed; for none are to be found in the sand-bed. But the varied productions of this third sea re-appear, and we again observe on the summit of Montmartre, Romainville, the hill of Nanteuil le-Hadouin, &c. the same shells as were found in the marls placed over the gypsum, which though really different from those of the coarse-grained limestone, are still considerably like them. Lastly, the sea withdraws entirely for the third time. Lakes or marshes of freshwater take its place, and cover with the remains of their inhabitants, the tops of almost all the

hills, and the surfaces also of some of the plains between them.

Such is a brief transcript of the admirable memoir of MM. Cuvier and Brogniart on the most interesting formation hitherto explored by the joint resources of geology and physiology. It exhibits an unfading picture of the convulsions which the primeval globe suffered, a few centuries prior to its close. The chalk beds of both the Paris and London basins evidently stood at first, near the level of that ancient ocean, as may be deduced from the billowy undulations on their surface. Had they lain deep under water, the rolling of the waves could not have chequered their face with those remarkable ridges and excavations, which still exist to indicate the cause of their origin.

1. It was about this geological epoch, that some of the great fields of basaltic-lava were poured forth from the interior of the globe, spreading over the secondary strata of chalk and sandstone, as we see exemplified in the north of Ireland, in Scotland, and many other countries. The epoch of the covering over of the great chalk formation of Antrim with basalt, coincides with the covering of the chalk basins of Paris and the Isle of Wight, with their tertiary strata. The acts of eruptive violence which immediately clothed the submarine chalk surface of one region with an immense sheet of lava, may have upheaved the chalk slightly above the level of the sea in another district not far distant, thus converting a marine basin into an estuary of great extent, which probably comprehended at once the

London, Isle of Wight, and Paris basins. For the depression between them that forms the bed of the English Channel, is very trifling in proportion to its extent of surface; and is very much exceeded in depth by the large continental lakes. The greatest observed depth of the water at the western extremity of the Channel, between the Land's End and Ushant, is only 70 fathoms, the distance between the two places being about 30 leagues of 30 to a degree; whereas the lake of Geneva is nearly double that depth between Lausanne and Evian, while the distance between the two latter places is only about 3 leagues. The greatest depth of water in the narrowest part of the Channel, between Dover and Cape Blanc Nez is thirty fathoms, and the distance 6 leagues; and between Cape La Hogue and the Isle of Portland, a distance of about 16 leagues, the depth of water is only 45 fathoms.*

2. The estuary cut off from the sea by alluvium at its mouth, would become progressively fresh by the influx of river streams, and change into a lake, on whose bottom, clay, vegetable remains, and freshwater shells would be deposited.

3. But as the phenomenon of trap veins transpiercing one another, proves that a series of submarine convulsions took place at successive periods, a second eruption of basalt might inundate the lake for a season with a shallow body of sea-water, introducing with it a colony of new inhabitants. By successive deposits of their exuviæ, along with calcareous matter and sand, the bottom would eventually rise above

* Mr. de la Beche; Geol. Trans. 2d Series, Vol. I. p. 89.

the tide level; and the sea would thus be slowly shut out, as the floodgate became more complete; the production of sea-shells would proportionally diminish, and cease entirely, as the sea withdrew, and the ground became once more, first a brackish marsh, and then a freshwater lake. (*Peu a peu cette production de coquilles diminue, et cesse tout-a-fait; la mer se retire, et le sol se couvre de laes d'eau douce.*)

4. Now were formed the solid deposits of marly limestone, as in the *travertino* of Italy: now the gypseous waters let fall their precipitate of soft plaster, which gradually consolidated round the bones of the *anoplotheria, palæotheria, birds, crocodiles, trionyx tortoises, palms,* and other productions of the tropical climate which then obviously must have prevailed in the latitudes of London and Paris. The period of the deluge was now drawing nigh, and partial dislocations of the strata, began to betoken that awful catastrophe. The ocean bed once more upheaved by a submarine expansive force, caused its waters to surmount the embouchure of the Parisian basin, and make it again an estuary of the sea.

5. Now the third marine formation of Brogniart or second above the chalk commenced, with its yellow clay-marls, its sandstone, and marine sands, its marl limestone, and upper sea marls. These deposits on reaching a certain height, necessarily became a barrier to the sea, reconverting the basin into a freshwater lake.

6. In this state it continued till by successive depositions, and the drainage of the waters, after

the deluge, it was finally brought into the existing condition.

Thus the vicissitudes of the land and ocean, portrayed in the tertiary formations, harmonise perfectly with other terraqueous phenomena of the same geological period. The whole may be regarded as characteristic preludes of that storm, which ere long destroyed the old world and its inhabitants.

§ VIII. CONCLUDING OBSERVATIONS ON TERTIARY STRATA.

These tertiary strata which a few years ago had been noticed only in the basins of Paris and London, are found to be most extensively distributed over the surface of the globe. Their existence is now familiar to us, in almost every state in Europe, particularly in the Sub-Appenine formations, where they have been so well described by Brocchi, and are now receiving further illustration from the able hand of Professor Guidotti of Parma. Again we trace them round the shores and in the islands of the Mediterranean; at Montpellier and Nice; at Savona, Volterra and Rome:—in the fish-beds of Mount Lebanon,—and the nummulite limestone that forms the foundation of the pyramids of Egypt. We recognise them also along the northern shores of Africa, and in Malta, Sicily and Sardinia. Mr. Strangways has traced them largely in the Steppes of Southern Russia—and on the shores of the Black Sea and the Caspian. The Russians in their expedition to Bokaria, have found them on the borders of Lake Aral; and finally on the authority of Mr. Crawfurd's discoveries, we establish

them in a considerable district of the Burmese empire beyond the Ganges.*

Mr. Colebrooke has pointed out analogies between the tertiary deposits of England and those of Caribari, which form a band at the base of the Thibetian mountains, and extending to Silhet, contain nummulites similar to those imbedded in the tertiary limestone of the Egyptian pyramids, and of frequent occurrence in the calcareous rocks of the same epoch in northern Italy. The beds of Caribari present the very association of organized remains, that characterise the tertiary strata of Europe, in which extinct genera of the Pachydermata have been discovered.†

The distribution of the tertiary strata in discontinuous patches and basins, is another interesting phenomenon in geology which has lately received illustration from the indefatigable science of Dr. Buckland.

Thus the tertiary beds of the London formation become gradually contracted in their progress westward through Berkshire, until they terminate in a point at Savernake Forest, between Hungerford and Marlborough. The strata of chalk on which these formations repose, dip inwardly from the circumference towards the axis of the basin, and sink nearly on all sides, beneath overlying beds of the plastic and London clays. To this arrangement, a remarkable exception occurs near the south-western extremity of the basin, a few miles to the south of

* Rev. Dr. Buckland. Geol. Trans. 2d Series, Vol. II. p. 387.

† Mr. Pentland, ibid. p. 394.

Newbury. Here, to the west of Kingsclere, there is a sudden and unusual elevation of the chalk, accompanied by fracture and an inverted dip. At Inkpen hill the chalk rises to the height of 1011 feet, its greatest elevation in England. The saddle form, or opposite dip from Inkpen to Highclere is seen in the chalk pits along the intermediate valleys.

The drainage of such valleys is generally effected by an aperture in one of their *lateral* escarpments, and not at either extremity of their longer axis, as would have happened had they been excavated simply by the sweeping force of water; and as it is utterly impossible, according to Dr. Buckland, to explain the origin of any valleys of this description by denudation alone, or of their terminal ridges, excepting by a force upheaving them from below, and elevating their strata along their central axis of fracture, he designates them by the title of *valleys of elevation;* making due allowance for the subsequent effect of diluvial denudation. A very decided example of a valley so formed, is that of the Weald of Kent and Sussex, already adverted to, p. 273. These phenomena may be regarded as of frequent occurrence in the formations of all ages, and as indicating the multitude of disturbing causes by which the earth's surface has been affected. The same evidence proves that the present inwards inclination of the southern edges of the basins of London and Hampshire has taken place since the deposition of the plastic, and probably of the London clay; synchronous with the Paris basin.

Now, do these plains afford any proof that the tertiary strata, which repose almost exclusively

within their basins, have been originally more continuous than they are at present, or perhaps united together? In fact, their disjoining hilly ridges, varying in height from 600 to 1000 feet, exhibit on their loftiest summits, traces of the ancient union of the tertiary strata. The separation into the two distinct basins of London and Hampshire, has resulted partly from local elevations and depressions by subterraneous violence, since the deposition of the plastic clay; and partly from the more recent removal of much of their substance, by diluvial denudations.

To this head belongs the remarkable fact of the occurrence of insulated portions of tertiary strata, as well as of chalk and greensand on the summits of the Savoy Alps, at elevations of more than 10,000 feet above the level of the sea; which seem to bear the same relation to the tertiary strata of the valleys of Italy, France, and Germany, that our trifling hills of Inkpen, Blackdown, and the North Downs, bear to the lower regions of the English basins. "As these Alpine deposits are contemporaneous fragments of the more extensive strata of the adjacent low countries, we are forced in explaining their present position, to adopt one or other of two conclusions; either that at the time of the deposition of these strata, the sea covered not only the highest portions of the chalk of England, but also the summits of the Savoy Alps; or, that since the deposition of these beds, by elevation of the mountains or depression of the valleys, or by the united effect of both these causes, the relative level of the one to the other has been changed to

an amount of many thousand feet. Now, as the undisturbed, and nearly horizontal position in which the tender and frangible materials of the tertiary strata still remain in the basins of Paris and Lombardy, forbids us to suppose that any depression could have brought them down so quietly to their present level, the theory of the elevation of those few portions which occupy the Alpine summits, remains by far the most probable that is submitted to our choice."*

The idea first suggested from the examination of the basins of Paris and Lombardy, that the tertiary strata were limited in their extent to certain hollow spaces, within the area of the chalk, has been proved to be incorrect, by the discovery of similar strata, very extensively over Europe; an excellent account of which has been recently given by M. Brogniart, in the 2d edition of his History of the Environs of Paris.

They have been found to occur also, as we have said, in the most distant regions of Asia, Africa, and America; so that deposits which were at first considered as simply local, are proved to be among the most extensive, as well as the most recent, that have taken place on the globe; and as their general position is certainly, for the most part, in the lowest spaces of the earth's surface, and their existence on mountain summits but an occasional and rare anomaly, the most simple solution of their appearance in such lofty situations, will be found in the hypothesis, that these mountains have been elevated

* Dr. Buckland—Geol. Trans. 2d Series, Vol. II. p. 119.

since the period at which the deposition of the tertiary strata took place.*

The freshwater formations of the tertiary strata of Paris, London, &c. have had much light thrown on their origin, by Mr. Lyell's masterly examination of the freshwater limestone, of Loch Bakie in Forfarshire.

This limestone resembles the *tufa* deposited by springs which issuing highly charged with carbonic acid or sulphuretted hydrogen from limestone strata, contain a quantity of lime in solution; as in Italy at the waterfall of Terni, at the baths of St. Philip on the frontiers of Tuscany some miles from Radicofani, and near Rome at the cascade of Tivoli, and the lakes of Tartari and Solfatarra. The modern deposit most analogous to that of the Bakie, is the limestone now forming daily under water at Czegled, and other plains in Hungary, as described by M. Beudant. It encloses *Planorbes* and other shells identical with those living in the neighbouring marshes. *It is traversed by irregular* tubes which *are perpendicular to the surface of the slabs*; and are considered by M. Beudant, as having been caused by the disengagement of gas.

Of the *ancient* freshwater limestones, the most similar to the rock marl of the Bakie are those of Italy. This kind of limestone having been quarried extensively by the Romans near Tivoli (Tibur) has acquired in Italy the name of travertino, (*lapis tiburtinus*), a term generally applied now to any modern tufa, or soft and cavernous limestone. The

* Dr. Buckland—Geol. Trans. 2d Series, Vol. II. p. 127.

travertino is white when first taken from the quarry, but after a time it becomes yellowish, and at length acquires that reddish hue which is so agreeable to the eye, and so much heightens the architectural effect of the monuments of ancient Rome. It is the material, in fact, of which not only the Coliseum and many other ancient works in Rome are constructed, but also the far older temples in the Grecian colony of Pæstum.

The long sinuous cavities which pass from the bottom to the top, so parallel to one another as to appear artificial, are considered by M. Brogniart as of invariable occurrence in the freshwater limestones of all countries, and as absolutely characteristic of such formations. He also traces the origin of the hills of travertino which bound the valley of the Elza in Tuscany, to rivulets actually existing which still deposit tufa, and which before the surface was modified by the eruptive and denudating violence of the deluge, flowed out, and deposited tufa on a level with the summit of those hills.

In the marl-loch of the Bakie, Mr. Lyell points out close analogies with the particulars recorded by MM. Cuvier and Brogniart of the freshwater deposits of the Paris basin. 1st, There is a very compact limestone, crystalline in parts; 2d, extensive deposits of white and yellowish calcareous marl, in which testaceous remains are of casual occurrence; 3d, vegetable remains wholly converted into limestone. The only distinctive feature in the ancient lacustrine deposits is the flints, either in nodules or calcareo-siliceous beds; but even these are formed by modern thermal waters under volcanic influence,

whence M. Brogniart conjectures that the silex of ancient freshwater formations was precipitated where we now find it, from the waters of thermal springs.

Between the aquatic plants and animals of the ancient and modern deposits, the closest relation subsists; the genera in the two cases being nearly identical. In both cases, among the testacea, are lymneæ, planorbes, &c.; among the crustacea—the genus cypris; and among the plants, the genus chara, with its fossilized seed-vessel the gyrogonite. Beautiful engravings of the fossil charas of the Bakie rock-marl accompany Mr. Lyell's very interesting paper.

The small point among the marginal figures, is the gyrogonite, or fossilized pericarpium of chara, found in the tufaceous limestone of the Bakie Loch; of the natural size. The large oval figure is the above magnified 20 diameters, and the round one, represents the lower end, to which the stem was attached. The *chara medicaginula* of the lower freshwater formation of the Isle of Wight is nearly twice the above size, and different in its spires.

The magnitude of the ancient freshwater lakes is not without modern parallel, though nowadays, the deposition has become comparatively slow from the reduced temperature, and smaller dimensions of the present race of European testacea.*

If this earth be a school of virtue to man under the direction of Providence, and if public calamities be requisite to maintain its moral discipline over the short-lived race of the present day, what

* Geol. Trans. 2d Series, Vol. II., p. 73.

penal prodigies would be necessary to restrain the wickedness of Cain and his apostate brood! The inspired historian does not indeed give, in his brief sketch of antediluvian society, any details of such occasional manifestations of Divine wrath, though the disordered fabric of the globe bears ample testimony to their repeated occurrence, but in his solemn account of the concluding catastrophe, he most explicitly ascribes the physical convulsions, to the indignation of Heaven. He tells us moreover, that Noah, favoured with a prophetic view of the coming calamity, built by Divine command a vast edifice of wood to float himself and family through an universal deluge, from which no other mode of escape would be possible. That Noah was commissioned to declare to the reckless mortals around him, the long-suffering of God, and to preach repentance, while the ark was preparing, St. Peter expressly informs us. We may readily imagine the derision with which the unparalleled architecture of the pious patriarch was regarded by his compatriots; and the insolent defiance with which they received the admonitions of the Almighty. That Noah's warning voice was seconded by miraculous powers over the phenomena of nature, we are not told. But as Moses, and all his great successors, were furnished with supernatural credentials of their prophetic mission, there is little reason to doubt that to Noah also such powers of controlling or predicting events might be delegated, as would strike terror, for a time at least, into the most depraved and the boldest hearts.

BOOK III.—THE DELUGE,

IN WHICH THE CAUSES OF THE ANTECEDENT REVOLUTIONS OF THE EARTH, AND ORGANIC BEINGS ARE CONSIDERED.

CHAP. I.—PHYSICAL RECORDS OF AN UNIVERSAL DELUGE, WHICH NEW-MODELLED THE EARTH.

"I CONCLUDE with MM. Deluc and Dolomieu," says the illustrious Cuvier, "that if there be any fact well established in geology, it is this, that the surface of our globe has suffered a great and sudden revolution, the period of which cannot be dated further back, than five or six thousand years. This revolution has on the one hand, ingulphed and caused to disappear, the countries formerly inhabited by men, and the animal species at present best known; and on the other, has laid bare the bottom of the last ocean, thus converting its channel into the now habitable earth."*

That a great expansive and subversive power exists within the crust of the earth, which has at remote periods, acted with prodigious force, raising up and laying dry those submarine strata, and transferring the waters of the ocean thence over ancient lands, is attested by innumerable phenomena. Concerning the chemical nature of this power, there can be little doubt. Modern volcanic eruptions, though merely its expiring efforts, clearly indicate, that the earthy and alkaline oxides of the terrestrial crust, exist interiorly in a metallic

* Baron Cuvier—Ossemens Fossiles, Discours Préliminaire, p. 134.

state, fused by the central heat, ready to produce explosion to any imaginable extent, on the influx of water.

Of this mighty deluge, the concomitant and effect of the transflux of the ocean which anciently covered a large portion of the present habitable earth, we have universal evidence. Nearly the whole table lands, and gentle acclivities of the mountains are covered with deposits of gravel and loam, to the production of which no cause now seen in action is adequate, and which can therefore be referred only to the waters of a sudden and transient deluge. This deposit is hence called *diluvium* by geologists. In it, the pebbles and loam are always promiscuously blended, whereas among the regular secondary and tertiary strata, they occur separate in alternate beds. The term *alluvium* is bestowed on the marl, sand, and gravel deposited by existing rivers and lakes, or on planes exposed to occasional inundation. The ablest writers, Cuvier, Buckland, Brogniart, Conybeare, &c. now adopt these distinctions.

"In the whole course of my geological travels," says the Rev. Dr. Buckland, "from Cornwall to Caithness, from Calais to the Carpathians, in Ireland or in Italy, I have scarcely ever gone a mile, without finding a perpetual succession of deposits of gravel, sand, or loam in situations that cannot be referred to the action of modern torrents, rivers or lakes, or any other existing causes; and with respect to the still more striking diluvial phenomenon of drifted masses of rocks, the greater part of the northern hemisphere, from *Moscow* to the *Mis-*

sissipi, is described by various geological travellers, as strewed on its hills as well as valleys, with blocks of granite and other rocks of enormous magnitude, which have been drifted (mostly in a direction from *north to south*) a distance sometimes of many hundred miles from their native beds, across mountains, and valleys, lakes, and seas, by a force of water, which must have possessed a velocity to which nothing that occurs in the actual state of the globe affords the slightest parallel."

Theorists, particularly of the Huttonian creed, have greatly overrated the disintegrating power of streams on the surface of the globe, and the consequent extent of common alluvium. Their fiction of cosmogony required a transfer of the mountain elevations and table-lands to the bottom of the sea, and they did not fail to paint their rapid transport, and deposition there. To the erosion of a streamlet, however inconsiderable its size, they ascribed the excavation of every great valley which it traversed. But this is often a mere thread, compared to the sloping width of the valley, and should at the utmost have produced merely a narrow and precipitous glen. The observed action of such a brook is rather to fill up the dell through which it glides, than to enlarge its dimensions. We may ask these theorists, how the *Gave* in the territory of Bearn, could scoop out *incognito*, so to speak, the profound excavation, in whose bottom it is encased, near the bases of the Pic de Bergon above St. Sauveur, between two natural walls, several hundred feet high, composed of very hard petrosilex (chert), the flat surfaces and acute angles of which display

through their whole height, no sign of erosion, or of the action of water, save at the very bottom, where the river has slightly rounded the rocky prominences, but always at the same level, though sweeping over the channel for so many ages? In fact, rivers occupy the bottom of the valleys, which were previously hollowed out by the diluvial deflux, to be presently described. An example will hardly be found of a valley, which can be legitimately ascribed to the action of the stream, that is seen passing through it.

Torrents indeed do exercise, on the surface of the earth a real digging and degrading action, yet from the meaning attached to the term, this action cannot be extensive; for a torrent is a stream of water running down a rapid slope. But on comparing the height of the most elevated summits of the earth, with the expanse of its surface, the total declivity of any river must be very gradual, its torrent force must be restrained to narrow limits, and its effect be confined to the formation of short and strait ravines. Even this action is for the most part merely local and transient, as every person may convince himself by visiting high mountain chains. It presents no remarkable effect except on the heaps of rubbish (diluvial) which cover the sides of the mountains; or on broken rocks, partially decomposed by other means; or on loose soil. The results of this very action tend to restrain it within still narrower limits, by strewing about on the valleys or plains at the outlets, the rubbish which the torrents had swept down. The elevation of the ground, a necessary consequence of the accumulated

debris, diminishes proportionally the slope, the rapidity, and the power of the water.

The impulsive force of great masses of running water is undoubted, and will be afterwards exemplified. But the operation of river torrents, appears great to us only because we judge according to the measure of our feeble means. But how slight and circumscribed are the changes thereby produced on the configuration of the globe, in comparison of those wide and long valleys, which in multitudes furrow the immense surface of the earth! It may be proved indeed that neither torrents nor the great existing water-runs have in any manner contributed to their formation.

Rivers while flowing amid their parent mountains, frequently partake of the character of torrents. Here they run sometimes with rapidity, in a great body, at the bottom of deep and narrow valleys. They seem incased in canals, hewn as it were out of perpendicular masonry. The first idea that occurs to every person who sees these facts for the first time, and who has reflected little upon them, is that the streams have scooped out these profound channels, and if the hardness of the rocks, and the height of the escarpments and mountains which flank them, appear too considerable and immense in reference to the small water courses which wind at their base, time by its continual operation is supposed to compensate for want of force.

Without stopping to examine what a long series of ages it would require for such rivers as we have described, or for the streams incased in the profound valleys of the Alps, the Pyrenees, and the Jura,

to be able to excavate these valleys, upon which their real action is so slow that nobody has hitherto been able to appreciate it; without inquiring at present whether this long series of ages will accord with other natural phenomena which do not permit us to suppose the existing state of the terrestrial surface to possess so remote an antiquity, it will be sufficient to relate here four sets of observations to be satisfied that the actual runs of water, even with a ten times greater volume than they have, could not possibly have excavated the profound channels on whose bottoms they flow.

1. We must first of all transport our imagination to the epoch when the two mountain ridges which now flank the actual valley on either side, were *not yet scooped out by the stream*, but were united, leaving between them no hollow, or at most, a slight primitive depression. The bottom of the valley being thus filled up from the origin of the stream, (for we must start from this point,) all along to the complete depression of the lateral hills into the level of the plain, the water would be much less rapid. Supposing, the same body of water, it must have flowed therefore with less velocity, and consequently with much less force. But, on the other hand, it must have had an immense force to be able to carry off a portion of ground which may be nearly represented by a triangular prism laid in the direction of its axis, having in many cases more than 500 yards in width, and a vertical thickness, sometimes equal to that, and often much greater. If to escape from this dilemma, a volume of water be supposed incomparably more considerable than what actually runs, to which such great effects are ascribed, much loftier and more extensive mountains must also be supposed in order to give origin to such an increased flow of water.

Were that hypothesis the only stumbling-block, and were there no direct observations besides to forbid the admission of that disgregating force, and its effect, we might pass onwards, but two other observations render the old water-wearing hypothesis inadmissible.

2. Historical documents all concur to prove, that streams possessing the greatest power that can be ascribed to them, have no appreciable erosive action, upon the rocks over which they run. It has not been remarked, that the greater part of cascades, cataracts or rapids, known and cited for many ages on account of their celebrity, have disappeared or even perceptibly diminished; or consequently that the natural dike which the stream encountered has been worn down or completely subverted. Cascades have not been observed to change into cataracts, and these again into rapids. From time immemorial the cataracts of the Nile have been talked of, as always preventing the navigation of that river; those of the Danube, the fall of the Rhine, &c. Since written records were known, we find the famous cascades of the Alps and Pyrenees, referred to; yet amid all these examples, we can notice hardly two or three cascades depressed, or cataracts smoothed away.

The only cascade that can be quoted as being really diminished in height, is that of Tungaska in Siberia. We do not mean to deny, that there may possibly be others. So many different causes besides erosion may contribute to lower a cascade, even to make it disappear altogether, that we should rather be surprised at the small number of known instances, than embarrassed by the objections thereby adduced; for the fall of a part of the rock, which forms the brink of the cascade; an abundant accumulation of rubbish at the foot of the escarpment; a real destruction of the loose soil from the upper strata of the mountain, are causes adequate to change the heights of water falls. These causes must occur pretty often; but how different is their action from that of erosion. This, if it existed in the Huttonian sense, would extend from the source of the stream down to its embouchure, exercising on the configuration of the surface of the earth, a considerable influence. Such, as we have pointed out, however, have so limited, so local an action, as to be hardly appreciable.

3. Granting, for a moment, that a stream endued with an erosive or comminuting force, of which we have no parallel, has been able to dig out the wide valley, at whose bottom it now runs in a state of weakness very different from its primitive condition, we must account for the immense mass of earth and rock which filled the valley before the stream had carried it away.

It is impossible to suppose that it was transported into the sea

many hundred miles distant from the valley: for it is known, that streams, on reaching the plains, lose their velocity, and let fall every thing which they held in suspension. We may, besides, remark, that several streams, on quitting the mountains, pass into lakes, where they deposit all the earthy matters which they held in suspension. This disposition is particularly striking in all the rivers of considerable size which descend from the ridges of the Alps on the north-west and south-east slopes of that chain of mountains. These streams, at the opening of the valleys which they traverse, fall into lakes which seem destined to purify them. Thus, on the northern slope we see the Rhone pass through the lake of Geneva; the Aar through the lakes of Brientz and Thun; the Rheuss through the lakes of the four Cantons; the Linth through the lake of Zurich; and the Rhine through the lake of Constance. On the southern declivity, the Lago Maggiore is traversed by the Ticino; the lake of Como by the Adda; the lake Desio by the Oglio; the lake of Guarda by the Mincio, &c. Now, these lakes, which are merely portions of the valleys, but of much greater depth, would have been filled up by the rubbish swept out of the upper valleys, if their excavation had had the origin which many have imagined. Rambling from hypothesis to hypothesis, it may perhaps be conjectured that these lakes had originally such a depth, that they could ingulf all the rubbish of the immense valleys without becoming full. But instead of getting entangled with such extravagant suppositions, why not admit, that the same unknown cause which hollowed out the bed of the lake, also hollowed out the valley, which is nothing more than its prolongation?

4. If actual and evident facts, however, proved that waters wear down rocks, scoop them out, and perpetually wash away their parts, we should perhaps be led to conclude, that causes of which we know absolutely nothing, and of which indeed we can form no idea, have given to the primitive streams the means of overcoming every obstacle. But observation seems to prove the very reverse.

It has been recently remarked by Brogniart, and long ago by Deluc, Dolomieu, Ramond, &c. that the rapid streams, which, in precipitous valleys, fall in cascades from rock to rock, and strike furiously against the lateral stone banks, produce no change whatever on these rocks; and that far from corroding their surface, they

allow them to get covered with a rich vegetation of mosses, conferræ, &c. a vegetation which could not subsist, nor even commence, if the least film of the surface of these rocks, were constantly, or even frequently, worn away.

A much more striking fact is presented by some of the great rivers, as the Nile and Oronoco, &c. which flow in the equatorial regions. These powerful streams, on their arrival in positions which confine, and, as it were, incase them between two walls of rock, form there impetuous cataracts. Their waters, endowed by the velocity of descent, with the greatest erosive, or disintegrating force that can be ascribed to this liquid, ought to wear away, or at least to smooth and polish the rocks which they have thus continued to strike since the creation of our existing continents; but so far are they from renewing their surface, that they cover them with a brown-coloured varnish of a peculiar nature.—*Brogniart. Eau. Dictionnaire des Sciences Naturelles.*

It appears then perfectly ascertained that water *alone* cannot hollow out rocks whose aggregation is entire, and that it can wear them in no degree, whatever be the velocity of its movement.

We say *water alone,* and we must insist on this distinction, to make the preceding facts accord with other facts which would otherwise appear contradictory.

We frequently observe furrows scooped in the solid walls, in which the streams under discussion are incased; we observe also rocks rounded, and entirely free from moss. But on examining the facts with attention, we shall remark that this erosion always occurs in the parts of the stream, where from the nature of the surrounding soil, the torrents carry along with them in their floods, fragments of stones separated from the banks. Now, it is by the action of these stones that the rocks in

the bed of the river are worn. It is easy to appreciate these circumstances. We shall perceive that this erosion never takes place at the mouths of the most copious springs, such are those of the Orbe, of the Sorgue at Vaucluse, &c. All the pebbles which could be carried off, have been removed long ago, and the mosses which grow abundantly on the rocks at the water level, as well as in the very bed of these torrents, are in no further danger of being destroyed by rolling stones. The same thing is observed in the succeeding portions of the stream, wherever a lake or excavation occurs capable of stopping all the hard bodies dragged forwards by the waters. Here, also the mosses grow luxuriantly, because they experience no other action than that of the water.

The actual streams, therefore, which bear the name of brooks and rivers, do not, when acting alone, appear to have any erosive power on uniformly aggregated rocks; unless some foreign cause such as ice or decomposition should break the rock into fragments. The absence of these extraneous circumstances is proved by the vegetation, or the varnish, which there covers the rocks exposed to the action of running waters.

As these streams recede from the grounds adjoining the high mountains where they took their rise, they gain often in volume what they lose in impetuosity; but this increase rarely compensates for their loss of speed; and although these great currents still retain a pretty considerable power of transmission in pushing onwards the new obstacles which oppose their progress, they are far from presenting

such striking results as torrents do. They stir up in their floods or changes of place, the loose earth and sands at their bottom, especially towards their banks, and transport them to some distance; but hardly can they move pebbles of the size even of an egg, lying in their channel and brought thither at other times and in other circumstances. After transporting the fine and loose mineral matters, they deposit them in places where their course is slackened by any cause, and thus raise up the bottom of the bed in these places; and they seek for a new passage in the middle of the dikes, which they have constructed themselves. The principal current is then directed sometimes to the one bank, sometimes to the other, and should it beat against the foot of a precipitous hill, composed of loose soil, it really wears it down, and makes it fall into the river. This now forced to abandon in whole or in part its former channel, transports into another part of its course, the earth resulting from the destruction of the hill, and thus creates new obstacles. Hence proceed the recent *alluvial* deposits which flank the streams wherever their course is slackened, and chiefly towards their embouchures.

We see, therefore, that even though the lands adjoining the valleys or gorges, were composed of loose matters, the waters now running along the bottom, could not have scooped out the valley, supposing them to have a twofold or even a tenfold force, above what they actually possess; the slope of the existing surface not being sufficiently great to give these masses of water the rapidity requisite to produce that effect, and to carry off the loose soil

which filled either the valley or the gorge. Finally the actual waters, so far from having contributed to form the long and numerous depressions which furrow the surface of the earth, under the names of valleys, vales, gorges, or clefts, continually tend to fill up these hollows, and rather to level the surface of the globe, than to plough it more profoundly.

Knowing the limited range of alluvial phenomena, we are now prepared to appreciate the nature and extent of the diluvial. We have, in our second part, considered the rocks replete with marine remains. These are spread over two-thirds of the surface of every part of our continents which have been explored. They abound at great elevations, rising to the loftiest summits of the Pyrenees, nearly 11,000 feet above the level of our present ocean, and to still loftier points in the Andes. It is remarkable that the true geographical summits of the Pyrenee ridge are composed of secondary shell-limestones, which surpass the granite, gneiss, and mica-slates, in elevation, and may have been deposited over the primitive rocks while they stood under the primeval ocean. In fact, the secondary rocks, red sandstone, alpine limestone, limestone of the Jura order, and trap, cover the primitive and transition rocks of the Pyrenees.

The great boulder stones fall under diluvial debris. On the secondary mountains of the Jura, particularly the slopes facing the Alps, a great many loose fragments of primitive rocks, some containing a thousand cubic yards, occur, strewed over the surface, at heights of 2,500 feet above the lake

of Geneva. They nowhere stand higher, or are more numerous than opposite to the largest and deepest valleys of the Alps. They have undoubtedly travelled across the line of these valleys, their composition proving clearly the mountain ridges from which they came. We may hence infer, that at the period of their transfer from the Savoy Alps, the lake of Geneva did not exist, otherwise they must have remained at its bottom, instead of being found on its opposite bounding mountain at a great elevation. The slope from the Mont Blanc ridge, was then a continuous plane to the Jura. This, and similar facts, indicate the scooping out of valleys between the mountains, by the pressure of the diluvial deflux. All the plains in the north of Europe exhibit on their surface, similar rolled boulder stones, fragments of primitive rocks, strewed over the tertiary strata. MM. Von Buch and Haussman have proved that these scattered blocks on the soil of Lower Germany, are identical in composition and nature with the mountain structure of Scandinavia, on the northern side of the Baltic sea. This ocean channel has also been hollowed out by the same deflux, carrying away the sloping plain which joined the two countries.

Analogous phenomena abound in England. The downs surrounding Bath are abruptly scarped, and are surrounded by valleys more than 600 feet deep. Yet on their very summits, flints are found which must have been transported thither from the distant chalk hills. These fragments must, like the above boulders, have been carried along by the first action of the currents, before the fury of the deflux

had excavated the valleys, and thereby intercepted all further communication with the locality of the flints.

Along the plains, at the foot of the extensive cliffs of the inferior oolite formation, on the borders of Gloucestershire, Northamptonshire, and Warwickshire, the accumulations of the diluvial gravel are of surprising magnitude. The materials thus assembled come from so many quarters, that it would not be difficult to form a nearly complete series of the geological formations of England, from the fragments found in these plains. Their distribution may serve in many cases to indicate the direction of the diluvial torrents. When rounded pebbles, mineralogically the same with rocks existing *in situ*, only in mountains to the north-west, are found scattered over the plains of the midland counties of England, it is obvious that they must have been drifted south-east by the waters. To trace these travelled fragments, to their native beds, often many hundred miles distant, affords an interesting search to the geologist; which mineralogical description can now render successful. It seems to be established that the deflux of the subsiding waters of the deluge, was in general determined *from* the mountain ridges down towards the plains. In Great Britain this would occasion a motion from the north-west towards the south-east, a direction proved by innumerable vestiges. The same forces that afterwards hollowed out the valleys, heaved up the diluvial gravel into hills of various size.

Besides the detritus of British rocks, there are found among the diluvial strata of England large

blocks and pebbles, the fragments of various primitive and transition rocks, which Doctor Buckland supposes to have been drifted from the nearest continental strata of Norway.

It is only to such a native source, that the pebbles of iridescent felspar, resembling Labradore which are found on the coast near Bridlington, can be referred. Many of the other pebbles of the English shores, may be identified with well-known mountain masses in Norway, and must have been drifted hither along with the diluvial detritus of clay and gravel through which they are disseminated. In the county of Durham, Doctor Buckland collected within a few miles' space on the north of Darlington, pebbles of more than 20 varieties of slate and greenstone rocks, that occur nowhere nearer than the lake district of Cumberland. In the street at Darlington, at the north end of the town, is a large block of granite, of the same variety with those at Shap, near Penrith. Similar blocks are found on the elevated plain of Sedgefield, on the south-east of Durham.

To these diluvial evidences, Sir James Hall has made some important additions, by the discovery of traces of the action of a mighty current on the surface of the hills and valleys near the city of Edinburgh. These districts are not only strewed over with the gravelly wreck of rocks that have been drifted to a great distance from their native bed by the force of violent waters; but channels and furrows may be observed on the surfaces of the hard rocks over which these waters not only drove the blocks and fragments of every substance that lay in the line of their course, but excavated deep valleys. When the covering of clay, protecting a mass of rock, is removed, its surface is found to resemble a wet road along which a number of heavy and irregular bodies have been recently dragged; as if every fragment had made a scratch as it passed.

The scratches are generally parallel to the general direction in which the diluvium has moved.

Similar appearances have been lately described by Mr. Murchison, Sec. Geol. Society, as occurring on the Braambury and Hare hills, the highest in geological position of the interesting Brora district in Sutherlandshire. These are celebrated for their quarries of siliceous white sandstone, abounding in fossils, and exhibit upon their sides and summits, distinct traces of a strong diluvial current, which has swept away their covering matter, and deposited in the plain of Clyne Milltown, a mass composed of the debris of the denuded hills, mixed with boulders of the coarse red conglomerate. A large portion of the turf having been recently removed, the surface of the rock is now seen to be scored with parallel lines, precisely similar to those observed in other places. And in this case, although the surface of the ground is very unequal, and the dip and bearings of the denuded strata vary considerably, the direction of the markings is uniformly from N.N.W. to E.S.E.

That these diluvial actions reached the summits of the lofty mountains, is evident from the boulder blocks of Mont Blanc thrown over on the high acclivities of the Jura chain. "The Alps and Carpathians, and all the other mountain regions I ever visited in Europe," says professor Buckland, "bear in the form of their component hills the same evidence of having been modified by the force of water, as do the hills of the lower regions of the earth; and in their valleys also where there was space to afford it a lodgment, I have always found

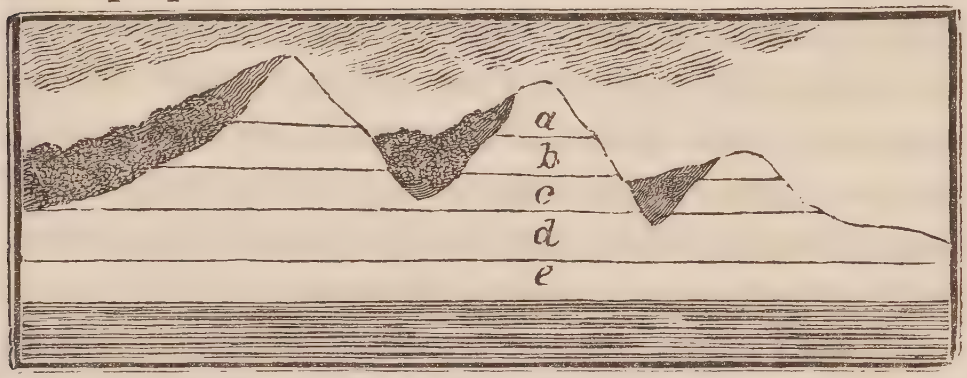
diluvial gravel of the same nature and origin with that of the plains below, and which can be clearly distinguished from the postdiluvian detritus of mountain torrents or rivers. The bones of the mastodon are found in diluvial gravel, in the Camp de Geans, near Santa Fe de Bagota in South America, 7800 feet above the level of the sea; and in the Cordilleras at an elevation of 7200 feet, near the volcano of Imbaburra, in the kingdom of Quito. M. Humboldt found a tooth of an extinct species of fossil elephant at Hue-huetoca on the plain of Mexico. Our high mountains in Europe are so peaked that animal remains though drifted round their summits, could hardly be expected to lie upon them, but would be washed down their steep slopes.

In central Asia, bones of horses and deer which were found at a height of 16,000 feet above the sea, in the Himmala mountains, are now deposited at the Royal College of Surgeons in London. They were got by the Chinese Tartars of Duba, in the north face of the snowy ridge of Kylas in lat. 32° N., out of the masses of ice that fall with the avalanches, from the regions of perpetual snow. The preceding facts attest, that "all the high hills that were under the whole heavens were covered," by the waters of the deluge.

There is a class of phenomena, clearly indicative of diluvial action, usually called valleys of denudation, to which we have already briefly adverted. Two excellent memoirs have been written upon them by Professor Buckland, in the Geological Transactions, vol. V. and Second Series, vol. I.

Hutchinson and Catcott showed long ago, that

the surface of the earth in many places, where it is at present furrowed by valleys, must have been formerly continuous: and this in innumerable instances *where streams do not exist at all;* in many chalk downs for example, or where the existing streams, as has been demonstrated already, are quite inadequate to the effect. Thus in a system of superposition such as is here represented, the



portions of the beds, *a*, *b*, and *c*, at present detached from each other, must once have been continuous: *d* has also been partially cut through, and *e* has been left untouched, merely because the excavation did not cut deep enough. The coasts of Dorset and Devon exhibit beautiful illustrations of this kind; the beds which are there intersected by valleys, nearly at right angles to the coast, being so different from each other, and so unlike in external aspect (chalk, green sand, oolite, lias, and red marl,) that there is no difficulty in tracing the continuation of the series on the opposite sides of the valleys, and no doubt of their former connexion. On passing along the coast to the east of Lyme and Sidmouth we cross nearly at right angles a continual succession of hills and valleys, the southern extremities of which are abruptly terminated by the sea: the valleys gradually sloping

into it, and the hills being abruptly truncated, and often overhanging the beach or under cliff, with a perpendicular precipice. The streams and rivers that run through them are short and inconsiderable, and incompetent even when flooded to move any thing more weighty than mud and sand. There is usually an exact correspondence in the structure of the hills which enclose each valley; so that whatever stratum is found on one side, recurs on the other side in the prolongation of its plane. Whenever there is a want of correspondence in the strata on the opposite sides of a valley, it may be referred to a change in the substrata upon which the excavating deluge had to exert its force.

If we examine the valleys that fall into the bay of Charmouth, from Burton on the east to Exmouth on the west, viz. that of the Bredy, the Brit, the Char, the Axe, the Sid, and the Otter, we shall find them all to be valleys of diluvian excavation; their flanks being similarly constructed of parallel and respectively identical beds; and the commencement of them all originating within the area, and on the south side of the escarpment of the green sand. The fact of excavation is evident from simple inspection of the manner in which the valleys intersect the coast, on the east of Sidmouth and the east of Lyme; and it requires but little effort, either of the eye or the imagination, to restore and fill up the lost portions of the strata that form the flanks of the valleys of Salcomb, Dunscomb, and Branscomb; or of Charmouth, Seatoun, and Bridport.

From the correspondence pointed out by Mr.

William Phillips, between the strata of Dover and the hills west of Calais; and by Mr. de la Beche, between the strata of the coast of Dorset and Devon, and those of Normandy, it may be inferred that the English Channel is a submarine valley, which owes its origin in a great measure to diluvial excavation, the opposite sides having as much correspondence as those of ordinary valleys on the land. Its depth is less, indeed, than that of the majority of the inland valleys which terminate in the bay of Charmouth.

In conclusion, Professor Buckland justly observes, that "though traces of diluvian action are most unequivocally visible over the surface of the whole earth, we must not attribute the origin of all valleys exclusively to that action. In such cases as we have been describing, the simple force of water, acting in mass on the surface of gently inclined and regular strata of chalk and oolite, is sufficient for the effects produced; but in other cases, more especially in mountain districts (where the greatest disturbances appear generally to have taken place), the original form in which the strata were deposited, the subsequent convulsions to which they have been exposed, and the fractures, elevations, and subsidences which have affected them, have contributed to produce valleys of various kinds on the surface of the earth, before it was submitted to that last catastrophe of an universal deluge which has finally modified them all.* *See Valleys of Elevation, p. 343.*

To the preceding geological proofs of the universal deluge, we must add our zoological witnesses,

* Reliquiæ Diluvianæ, 2d Edition, p. 258.

—the numerous remains of extinct species of land animals, dispersed through the superficial gravel all over the earth; phenomena to be examined in a subsequent chapter.

Other appearances in the strata have been referred to the denudating force of a mighty deluge. In the granites of the upper Vivarais we behold mountains seemingly torn asunder, immense mural precipices, terminated by acute angles, and enclosing between them the most frightful chasms. Mount Cervin an insulated pyramid more than 3000 feet high, placed on the loftiest ridge of the Alpine chain, is an eloquent witness of the great aqueous catastrophe. "However keen a partisan I am of crystallization," says Saussure, "it is impossible for me to believe that such an obelisk, issued directly from the hands of nature, in this form. The surrounding matter has been broken off and swept away; for nothing is to be seen around it, but other summits, springing like it, abruptly out of the ground, with their flanks in like manner, abraded by violence."

At Greiffenstein in Saxony in a gneiss district, separate columns, or rather thin granitic prisms are seen rising from the plain, more than a hundred feet high. These are divided by horizontal fissures or joints into successive courses, or we might say tables, so that each column seems built of great slabs of granite regularly piled over each other. Certainly no person, on viewing these pillars and the subjacent level ground, will believe that they were formed as they stand, either by crystallization in a menstruum, or shot up by igneous eruption, or left alone after subsidence of the plain. They are manifestly the

remains of a great field of granite which once covered the whole space, like many other districts in the neighbourhood, but which was dislocated, ploughed up, and excavated at the universal deluge.

The mountains called *moles*, which rise insulated from the centre of extensive plains, seem also to be the diluvial debris of some great mineral districts of which they formed portions. The Landscrone may be adduced as a good example. It is a mountain placed in the middle of the plains of Lusace, about 2 leagues from the foot of the chain which bounds this country to the south, and presents the figure of a sugar loaf, nearly a thousand feet high, with the summit cut off. Like the territory, and the mountain chain in the neighbourhood, it consists of granite, capped over its whole top, with a platform of basalt, from 220 to 250 feet thick. This basalt is merely an insulated portion of the general *coulee*, that covers the granite district, about 2 leagues from it. It is hence obvious that the intermediate table land must have been swept away; for no one can possibly conceive of a basaltic lava effused on the top of an insulated cone of such elevation.

Mount Meissner in Hesse, six leagues south-east of Cassel, also deserves to be noticed here. It rises, colossus-like above the surrounding mountains, from which, however, it is completely insulated. Its summit forms a plain, 2 leagues long, and 1 league broad, at a height of more than 1900 feet above the river which flows at its base, and about 2200 feet above the level of the sea. The body of the mountain, in common with the country all around, consists of shell-limestone and sandstone.

Above these, on a stratum of sand, a bed of fossil wood reposes, one hundred feet thick in several places. This wooden floor is covered by a vast pavement or *coulee* of basalt, from 300 to 500 feet thick, which composes the upper platform. An observer who studies the composition of this interesting mountain and of the neighbouring districts, cannot help concluding that the enormous pile of wood, imbedded at such a height above the existing country, must have been drifted thither (for such a mass of trees could never have grown in one place), while the surface was yet continuous and depressed. The basalt must have been thereafter effused over them, obviously in a lava state. The explosive forces under the ocean bed which caused the deluge, first upheaved the general mountain masses, and the retiring deflux excavated the strata round Mount Meissner, leaving it an insulated mole, towering boldly above all the country, through an area of nearly 40 miles.

The geognostic student sees in the organic remains of the secondary formations, described in Book Second, irresistible proofs that many strata of our present dry land, were deposited under the ocean. I conceive, moreover, that good evidence of the former submarine position of a large portion of the earth, is afforded by the saline impregnation of many of its extensive plains. Every traveller through the deserts of Africa and Arabia, describes the soil to be salt, and the water to be brackish, in almost every district. The subsoil is generally clay, which prevents the saline matter from being washed deep into the ground by the tropical rains.

In the sands bordering on Egypt, the salt occurs often in balls and irregular lumps; and the great desert of Barbary is in some places covered with a saline crust, of such whiteness as to resemble statuary marble, and of such thickness as to be quarried into square blocks, for building houses. It is applied to the same purpose at Ormutz in Persia. Olivier states in his Persian Travels, that the great plains, or deserts of that country consist of an argillaceous soil impregnated with salt. "This substance," says he, "is so abundant in that country, that being washed down by the rains, saline pools are formed in winter over the low grounds, almost every lake is more or less brackish." The great plains or steppes of Siberia are formed of clay, and present analogous phenomena, especially northward of the Caspian Sea, where a multitude of lakes occur, some fresh, others rendered saline by the muriate or sulphate of soda. The lake of Indersk 20 leagues in circumference, has its bottom covered with a crust of salt, like a cake of ice, more than six inches thick, hard as stone, and perfectly white. The argillaceous soil of the great table land of Mexico was found by Humboldt to be quite impregnated with salt. The lake of Penon Blanco, that dries up every summer, forms the great mine of salt for Mexico; from which more than 15,000 tons are annually carried away.

CHAP. II.—CAUSES OF GEOLOGICAL CATASTROPHE.

In the Newtonian Philosophy, no other causes of natural events can be admitted than what are known

to be really operative, and adequate to account for the phenomena. This inductive law prohibits the employment of hypothetical assumptions, whose existence we cannot prove, such as the attraction of a comet in deranging the axis of the earth, or deluging it, by lifting the waters from their ocean bed. Nor will modern discovery suffer the theorist to summon from the bowels of the earth an ideal abyss to serve his purposes; far less allow him to get rid of a meteoric deluge imported by an aqueous *coma* for the occasion. Thus wisely circumscribed, but by no means fettered, we shall have no difficulty in finding actual and potential forces, capable of explaining the principal appearances, incident to the great diluvial catastrophe, and its precursor inundations. Eruptive powers similar to those which raised the primordial land, acting under the bottom of the primeval ocean, rolled its waters over the ancient continents, many of which were broken down and sunk in the sea, whilst new territories were upheaved and laid bare. We shall endeavour to establish these propositions by an extensive induction of well established facts, illustrative of volcanic agency, and basaltic eruption.

§ I. VOLCANIC ACTION.

This power, though sufficiently terrific in many of its recorded forms, has now a very limited range in comparison with its ancient extent, even in postdiluvian periods. Thus the extinct volcanoes of the Rhine, Hungary, Auvergne, and Italy, indicate a far greater magnitude of eruptive fire, than any described in history. Those which are now seen

issuing from conical chimnies, are merely the expiring fumes of those furnaces, that have once desolated whole regions of the earth. Of this fact, we have convincing evidence in France, which has never been visited by volcanic fire, within the memory of man; yet there is no country where volcanic products exist in greater variety, in closer affinity with one another, or in more interesting forms, than in the heart of that kingdom. Travelling in that territory from the north, the first volcanic lavas occur in Auvergne, to the west of Clermont, on the granite table-land bounded by the rivers Allier and Sionle. Extinct volcanoes, to the number of 100 appear in an immense range of insulated conical hills about 700 feet in height, formed of masses of solid lava, and spongy scoriæ. Their tops are hollowed out in the crater form, the edges of the cup being in many cases entire and well defined. The streams of lava are blistery on the surface, and bristling with scoriform asperities, which rise sometimes three feet high. The deeper we penetrate into the mass, it becomes less cellular and more compact, exactly as in modern lava streams; yet the basis occasionally differs in no respect from that of the finer basaltic prisms, including like it, grains or crystals of augite, olivine, and felspar. The lavas have sometimes spread widely over the plains, and at others flowed into narrow valleys, following their windings through a distance of 9 or 10 miles. In their progress, they have obviously taken the lowest track, bending over or gliding about, the rising grounds which obstructed their advance, and like every stream of liquid mat-

ter, have observed strictly the laws of hydrostatics. The natural history of these lavas is therefore complete, and needs no aid of fancy to identify their volcanic source ; for we perceive the focus that poured them out, the path they percurred, the obstacles they shunned, and the strata which they overwhelmed and still cover.

In the same district, there also occur genuine basalts, or submarine lavas of more ancient date, being anterior to the excavation of the valleys, while the lava streams are evidently posterior to this event. The basalts appear under the form of horizontal *coulees*, or sheets, covering portions of elevated land since upheaved, or constituting the caps of mountain chains and insulated peaks. These are shreds of antediluvian and diluvian lavas.

In Velay and Vivarais volcanic lava forms a great portion of the surface of the ground, exhibiting in certain spots, interesting phenomena. Near Montpesat, Thueys, and Jaujac, small extinct volcanic hills are still to be observed ; and a stream of lava may be traced from the foot of each, running down the valleys. The shape of these currents is perfectly defined. Their bottom reposes on a stratum of pebbly gravel, and is altogether scoriform ; while higher up the lava is split into most regular prisms, as sonorous as metallic iron, and in beautiful colonnades. The basis of the lava is black coloured and compact, containing grains of olivine and augite. It has flowed evidently after the excavation of the valleys. Similar appearances pervade the south of France down to the Mediterranean shores. Near Agde, the extinct volcano of St. Loup occurs,

composed of cellular lavas; which have been employed in the hydraulic architecture of the canal of Languedoc.

The volcanic remains of central France have been recently illustrated by two ingenious practical geologists, Dr. Daubeny and Mr. Scrope; from the latter of whom I shall select a few facts, as they have been well arranged in the Quarterly Review for October 1827. The associated rocks of igneous origin seem scarcely in any instance to have been repeated in the same spot, but to have burst forth singly and successively on different though neighbouring points, remarkable for their general distribution in a line from North to South; a direction coincident with that of the granitic beds, from whose interior they have apparently burst forth. To the west of the valley of the Limagne, immediately behind Clermont, rises a granitic *plateau*, about 1600 feet above the valley, and 3000 above the sea. On this rests a chain of volcanic hills about 70 in number, composed of steep truncated cones, called the Puys of the Monts Dome, which form with the ashes and scoriæ scattered around, an irregular ridge, from 500 to 1000 feet high, and about 18 miles in length by 2 in breadth. They consist of loose scoriæ, blocks of lava, lapillo, and puzzolana, with fragments of trachyte,* and granite. The

* Trachyte is a volcanic rock, characterised by its porphyritic structure; its scorified and cellular aspect; its harsh feel (whence its name rough-stone); and by the imbedded crystals of glassy felspar. These minerals are sometimes impasted in a felspathic light coloured cement. It is a rock entirely absent in the British islands; but the clay porphyry associated with red sandstone in the island of Arran, and that of Sandy

lava-currents, traceable to the craters of these cones, present the image of a black and stormy sea of viscid matter, suddenly congealed at the moment of its wildest agitation.

One of the largest volcanic cones of the district, the Petit Puy de Dome, has a very regular crater 300 feet in width and depth, elevated more than four thousand feet above the level of the sea. It consists entirely of fragmentary matter, basaltic scoriæ, sand and ashes. The Puy de Louchadière is the most striking of the chain. Completely insulated from the others, it rises at an angle of 35°, in a majestic cone to the height of more than 1000 feet from the western plain, forming a total elevation of 3956 feet.

Mont Dor is a mountainous tract, the higher portion of which is divided into seven or eight rocky summits, grouped together within a circuit of about a mile in diameter, the highest rising to 6217 feet above the level of the sea. The whole of this mass consists of successive beds of volcanic origin, and of immense thickness, which almost conceal the primitive soil. The currents of basalt have flowed on all sides to the distance of fifteen, twenty, and in some instances twenty-five or thirty miles from the central heights. The *plateaux* of trachyte on the contrary, rarely extend beyond a circle of ten miles radius; but what the latter currents want in length, they possess in height and breadth.

In the ancient province of Velay, Mr. Scrope

Brae presents numerous analogies. Some modern lavas of Vesuvius approach very nearly in composition and appearance to trachyte, and the oldest volcanic products on Ætna and Teneriffe are composed of it.

counted more than a hundred and fifty cones, so thickly sown along the axis of the granitic range, that separates the Loire and Allier from Palhaguet to Pradelle, as generally to touch each other by their bases, and thus to form an almost continuous chain.

Germany, particularly on the banks of the Rhine, in Hessia, Saxony and Bohemia, presents a great many remains of basaltic lava-streams, accompanied often with clinkstones, in mountain groups. In some localities, volcanic tufas, with cellular and scoriform lavas occur.

It is hardly necessary to say that Sicily and Italy particularly in the Vicentin, the environs of Rome, and Naples, include extensive volcanic formations. No less than 60 ancient craters have been specified in a small tract of Italy. When these were active, what a frightful region must it have been!

There are at present 205 burning volcanoes on the globe. 107 of these occur in islands, and 98 on continents, but ranged mostly along their shores. The American volcanoes are among those most distant from the sea. In Peru, they are about 70 miles from it. The volcano Popocatepec is 140 miles inland, but it merely smokes.

We owe to missionary zeal, an acquaintance with the most remarkable volcano ever described, in the island of Owhyhee, where several exist in an active state. Mouna Roa, a mountain of trachytic formation estimated to rise to the prodigious height of 15000 feet, contains an enormous crater, 8 miles in circumference, and includes a vast lake of molten lava, subject to horrific explosions and undulations.

The crater, instead of being the truncated top of a mountain, distinguishable at a distance in every direction, is an immense chasm in an upland country, near the base of the mountain, and is approached not by ascending a cone, but by descending two vast terraces. It is not visible from any point, at a greater distance than half a mile. The whole summit of its ancient cone seems to have fallen in, and formed the precipitous ruins which encircle the crater to a distance of from 15 to 20 miles. The crater is 6 or 7 leagues from the sea, and of elliptic form. The bottom of the gulf within, has a circumference of 5 or 6 miles; and a depth of 1500 feet, the descent being in general practicable. When Mr. Goodrich visited this crater for the first time in 1824, he remarked in the cavity, 12 distinct places covered with red hot lava, and 3 or 4 from which it spouted to the height of 30 or 40 feet. At 1000 feet above the bottom, there was observable round the inner surface of the hollow cone, a black border, which he considered to be the trace of the height to which the melted lava had recently risen before breaking through an opening for itself into the sea, by some subterranean channel.

Sulphurous exhalations of variable colour and density escape from all the fissures of the lava crust, producing here and there a blast like strong vapour blowing out of a steam boiler. The pumice stones found in great abundance all round the crater, are so light, porous, and delicate in texture, that it is difficult to preserve specimens of them entire. Fibrous capillary filaments, similar to those collected after every eruption of the volcano in the isle of

Bourbon, cover the ground about the crater to a thickness of 2 or 3 inches. The wind sometimes transports these filaments to a distance of 6 or 7 leagues. A party from the Blonde frigate, which not long since visited the crater, represent the first impression of the lurid gulf within, when viewed from its brink, as surpassing all powers of description. From the margin, said they, we looked down for more than 1300 feet, over rocks of lava and columns of sulphur, between whose antique fissures a few green shrubs and berry-bearing plants, clung to a rugged soil, where many a cone, raised by the action of the fire below, was throwing up columns of liquid flame, with whirls of smoke and vapour; while floods of liquid fire were slowly rolling among scoriæ and ashes, here yellow with sulphur, and there black, gray, or red, as the substance varied in hue against which the flames played. Not less than 50 cones, of various heights appeared below us, one half of which were active chimnies of volcanic fire. The older cones frequently fall in, and are constantly replaced by new ones. Some of them eject fragments of rock, others only ashes, while lava or boiling water issues from their sides. Many of the cones emit vapours which condense into sulphur beds of beautiful forms. The roaring of the elements bursting their prison, added greatly to the horror of the scene.

" A whole lake of fire was seen to open suddenly up, in a part at a little distance. This lake could not have been less than two miles in circumference, and its action was more horribly sublime, than any thing I ever imagined to exist, even in the idler

visions of unearthly things. Its surface had all the agitation of an ocean. Billow after billow tossed its monstrous bosom into the air, and occasionally the waves from opposite directions met with such violence, as to dash the fiery spray, in the concussion, forty or fifty feet high."*

Two immense peaked mountains rise out of the north-east, and south-west extremities of the central table land of Owhyhee, the former named Mouna Kea, or the White mountain, supposed to be 18000, and the latter Mouna Roa 15000 feet high. The steep declivity of the table land, which at different distances from the coast, rises into a continued ridge, from 3000 to 6000 feet in height, is perforated with innumerable craters, whose floods of melted lava have from time to time encroached considerably on the sea. About 25 years ago, an eruption from the summit of Mouna Huararai, a part of the ridge on the western side, estimated at 8000 feet in height, poured forth a torrent of lava, which overwhelmed in its course several villages, destroyed numerous plantations and fish-ponds, and filled up the deep bay of Kirauea, to the extent of 20 miles in length, forming an entirely new line of coast.†

* Rev. Charles Stewart, August 26, 1825; letter in Silliman's Journal.

† Peli, probably the superstitious title of the Kirauea fires, has lately acquired peculiar interest, as the scene of sublime heroism in a female. The barbarous natives had long worshipped the mysterious powers of nature that rage in this place. They supposed the gods of the island to have their abode here, requiring to be propitiated by perpetual oblations, and punishing every violation of their sanctuary with instant destruction. This worship is now no more; it has been abolished by a Christian convert of high rank, Kapiolani. At the edge of the first preci-

Among the Friendly islands, three volcanoes are known to exist. Tafooa, one of them, contains a volcano which the natives worship as the abode of a divinity. Eap, to the eastward of the Caroline islands, is volcanic, and is subject to frequent earthquakes.

The position of all our active volcanoes in the neighbourhood of the ocean, is a very striking fact. It becomes much more so when we observe submarine volcanoes burning in the very bosom of the sea. The little islets, and other phenomena, which they have been observed to produce at Santorini, on the shores of Iceland, near the Azores, &c., leave no doubt of their existence. The writers of antiquity speak frequently of islands which were seen to rise out of the Grecian seas. "The celebrated islands of Delos and Rhodes," says the elder Pliny, "according to tradition, are sea-born; afterwards lesser islands were observed to spring up, such as Anaphe beyond Melos; Nea, between Leranos and the Hellespont; *Alone*, between Labedos and Theos; *Thera* and *Theresia* amid the Cyclades, in the 4th year of the 135th Olympiad; *Hiera* situated between the two preceding, 130 years afterwards.

pice that bounds the sunken plain, many of her friends and dependents lost courage and turned back. At the second, the rest earnestly entreated her to desist from her dangerous enterprise, and to tempt no further the powerful gods of the fires. But she proceeded, saying, "I will descend into the crater, and if I do not return safe, then continue to worship Peli; but if I come back unhurt, you must learn to adore the God that created Peli." With unhesitating step she reached the gloomy abyss, stirred the fiery lake, and completed an achievement, seldom equalled in the annals of magnanimity. When she pushed the stick into the glowing lava, the idolatrous natives had expected to see her instantly fall a sacrifice to their insulted goddess.

In our own time, 110 years since the above period, under the consulate of M. Junius Silanus and L. Bulbus, *Thia* appeared." Strabo asserts positively, that Hiera was produced in the midst of flames. Plutarch and Justin relate that its formation was accompanied with much fire, and great ebullition in the sea.

On the 23d May 1707, at sun-rise, there was observed in the sea at a league from the island of Santorini, a floating rock. Some sailors mistook it for a ship ready to founder, and they pulled towards it, with the view of pillage. On arriving, they ventured to alight upon it, and they carried off some pumice stones, with oysters sticking to them. In a few days, the rock became stationary, forming a little island, which rapidly increased in size. The sea now began to be agitated, and a degree of heat and sulphurous fumes pervaded the island, which prevented its being approached. On the 16th July, 17 or 18 black rocks rose along side of the island; on the 18th there issued from it, for the first time, a dense smoke, while subterranean bellowings were heard; on the 19th the fire began to appear, and gradually increased in fury. During the night, the island seemed to be nothing but a multitude of furnaces vomiting flames. Its magnitude increased, so that the noxious fumes became intolerable at Santorini. The sea boiled violently, and threw dead fish on the neighbouring shores. The submarine noises rivalled the sound of furious cannonading; while the fire made new openings, which projected showers of red-hot ashes and stones, sometimes to a distance of more than two leagues. This interest-

ing state of things lasted for a year. Five hundred paces from the island, the sea felt scalding hot to the hand, and melted away the pitch from boats, which had therefore to be prepared for the volcanic trip, by an extra caulking.

For 10 years after the formation of the new island, the volcano made several eruptions—but when examined in 1772 by M. de Choiseul, it was quite inactive; and a large quantity of bitumen and sulphur was observed oozing out of its shores.

Captain Tillard of the Royal Navy described in the Phil. Trans. for 1812, an analogous phenomenon which presented itself to his notice near the Azores. About a mile from the north-west cliffs of St. Michael's, within the sea, a volcano sprung up. From this part of the water an immense body of smoke was seen to rise, from which suddenly burst forth a black column of cinders, ashes, and stones, in the form of a spire inclined to the perpendicular at an angle of from ten to twenty degrees. During these eruptions, vivid flashes of lightning continually issued from the densest part of the volcanic smoke, accompanied with occasional water spouts. The part of the sea where the volcano was situated, was upwards of thirty fathoms deep. The volcano had lasted four days, when a crater began to form at the surface of the water, the edges of which rapidly rose to 20 feet above its level, with a diameter of about 400 feet The contiguous cliffs of St. Michael's were at this period shattered by a shock of an earthquake. The mouth of the crater facing St. Michael's was nearly level with the sea, though in other parts it eventually rose to a height of fully 200 feet. It

was filled with boiling hot water, which overflowed into the sea by a small channel of six yards broad; through which it was probably filled again at high water. This stream, close to the margin of the sea, was so hot, as to scald the fingers when they were suffered to remain in it a few seconds; and great numbers of fish were destroyed during the early part of the eruption. This island, called *Sabrina*, after the name of Captain Tillard's ship, was not long visible, for in 1812 nothing but a little smoke or steam was perceived to rise from the sea, where the volcanic ashes had been thrown up.

Appearances altogether similar occurred on May 10, 1814, during serene weather, on the coast of Kamtschatka.

In the history of volcanic eruptions, frequent mention is made of torrents of water and mud ejected by volcanoes. Bouguer and Condamine saw these formidable torrents tear up the surface of a whole country. Six hours after an explosion of Cotopaxi, a village nearly 80 miles distant in a straight line, and probably 140 by the winding channel, was entirely swept away by the flood. In 1698 the volcano of Carguarazo, contiguous to and probably connected with Chimboraço, sunk in, and covered nearly 50 square miles of country with mud. It is not in fact by burning lavas, that the volcanoes of Peru and Quito exercise their ravages, but by torrents of mud and water. The mud, when first ejected, has the consistence of pap, but it speedily hardens; and occasionally contains so much black combustible matter, that the inhabitants make use of it afterwards for fuel. Sometimes the muddy waters

that flow from subterranean caverns, carry along with them a vast quantity of small fishes. These are a species of glutinous *pimelodes* (*pimelodes cyclopum.* Humb.), of which the largest are scarcely 4 inches long. Their number is often so considerable, that by putrifying they breed a pestilence in the country. They are of the same species as those living in the native streams; from which it would appear that there are certain communications between the upper level of the volcanic lakes in the interior of the mountains, and the surface of the external land. The wonderful circumstance is, that they are raised up from that level 8000 or 9000 feet high, and ejected from the crater with very little injury.

The masses of water and mud, in the preceding cases, are probably due to local peculiarities. There can however be no doubt that the expansion of water by heat into steam, forms the eruptive agent which elevates and throws out the liquid lavas of volcanoes, as well as the showers of ashes and stones. The fountains of the Geysers in Iceland, indisputably prove the volcanic agency of steam, so that Savery's engine is merely a miniature model of the mechanism employed by nature, on a magnificent scale, to give projectile force to her jets of hot water in Iceland. "For an hour and a half," says an intelligent traveller, "the column rose without interruption 150 feet high, being 17 feet thick at its greatest diameter; and spouted up with such energy, that it retained near the top, the same dimensions and the same figure as at the base. On throwing stones into the volcanic gulf, they were

seen to mount instantly with the column of water, and even to reach a still greater height with astonishing velocity."

Great volcanic eruptions are usually accompanied with very heavy rains, which inundate the contiguous regions. The sea seems to sympathise with the agitations of the adjoining volcanoes; rising and falling in rapid alternation. We may ascribe to a similar oscillation the depression which it suddenly undergoes in the neighbourhood of a volcano, at the crisis of an eruption, caused by the sudden deflux of a great body of water into the vast volcanic caverns. Earthquakes and volcanoes are intimately related. They are, says D'Aubuisson, most likely the effects of the same agents, or subterranean fires. In the tremendous earthquake which destroyed Lima in 1746, four volcanoes were opened up in one night, and the agitation of the ground immediately ceased. The deeper seated the explosive forces are, the more extensive and sudden is the concussion. At Cumana in 1812, the first shock lasted 6 seconds, the second 12; then a very loud subterranean noise was heard, followed by a perpendicular movement of 3 or 4 seconds' duration, which was terminated by a longer continued undulatory motion. Nothing on the surface of the ground could resist these cross oscillations. The city was totally overthrown, leaving only the cathedral. The ocean is very violently agitated by earthquakes. At that which desolated Lisbon in 1755, even the British and Norwegian seas felt the shock; and at the same instant the whole land of Portugal and Andalusia vibrated. In Africa when the

cities of Morocco, Fez, and Mequinez were in a great degree destroyed, the sensation of the earthquake was perceived over a large portion of Spain, France, Switzerland, and Germany. The shock that ruined Lima, was propagated across the continent of America, and the Atlantic Ocean, even to Europe. A violent earthquake which not long ago overturned some houses at Constantinople, caused a concussion at Petersburgh. On the 8th Sept. 1601, between one and two o'clock in the morning, a considerable earthquake shook the whole of Europe and Asia.

Till Sir H. Davy's splendid discoveries of the metallic bases of the earths and alkalis in 1807 and 1808, no hypothesis explanatory of volcanoes had been offered which was entitled to the slightest respect. Ever since that most illustrious era, however, I have regarded the theory of volcanic action, equally complete and satisfactory, with most of our physical inductions. It is therefore peculiarly gratifying to find that its celebrated author has himself finally favoured the world with the development of views so entirely his own.

The metals of the alkalis and earths from their paramount affinity for oxygen, could not possibly exist on the surface, but only in the interior of the globe. On this principle, volcanic fires would be occasioned whenever these metals were extensively exposed to the action of air and water. Thus also, the formation of lavas might be explained, as well as that of granites, porphyries, basalts, and many other crystalline rocks, from the slow cooling of

the products of combustion or oxidation of these remarkable substances.

This opinion was announced by Sir H. in a paper published in the Philosophical Transactions for 1808; and illustrated in the lecture room of the Royal Institution, by beautiful experiments which I had the pleasure of witnessing in 1809. Since 1812 he has endeavoured to gain evidence respecting it, by an examination of volcanic phenomena of ancient and recent occurrence in various parts of Europe. The active volcano on which he made his observations is Vesuvius; than which, there is probably no other so admirably fitted for the purpose, from its vicinity to a great city, the facility with which it may be ascended in every season of the year, and the nature of its activity.

On the 5th December, 1819, he had an opportunity of examining a stream of lava flowing freely from an aperture in the mountain, a little below the crater. The crater itself emitted so large a quantity of smoke, with muriatic and sulphurous acid fumes, that it could be approached only in the direction of the wind; and it threw up every two or three minutes, showers of red-hot stones. At an aperture about 100 yards below, the lava flowed, as if forced out by elastic fluids with a noise like that made by steam issuing from a high pressure engine boiler. It rose perfectly fluid, in a stream of from 5 to 6 feet diameter, and immediately fell as a cataract, into a chasm about 40 feet below, where it was lost under a kind of bridge of cooled lava—60 or 70 yards farther down, the stream reappeared.

On issuing from the mountain, it was nearly white hot, and exhibited an appearance similar to that produced by plunging a pole of wood into the melted copper of a foundery; its surface being violently agitated with the escape of large bubbles, which burst into a white smoke. Under the bridge, the lava seemed red-hot in the sunshine. The force of its current was so great, that the guide, a very stout young man, could not hold a long iron rod in it. During the whole of its course, which was nearly three quarters of a mile, it threw off clouds of white smoke, except at two or three interruptions where it flowed under a cooled surface. As the smoke diminished, it cooled and became pasty; but even where it terminated in moving masses of scoriæ, smoke was still visible, especially on stirring them up, or the red-hot lava in the interior.

Next day Sir H. approached within four or five feet of the lava aperture, and examined the vapour close to it, by chemical reagents. From an eddy in the hollow of the rock over which it fell, he lifted some of the lava in an iron ladle, and ascertained by experiment whether any combustion was going on at the moment of its issue from the mountain. There was certainly no appearance of more vivid ignition in consequence of its exposure to the air, nor did it glow with more intensity when it was raised in the ladle. He put the circumstance, however, beyond the possibility of doubt, by pouring some of the fused lava into a glass bottle containing siliceous sand at the bottom; and furnished with a ground stopper. He closed it at the moment, and

examined the air at his leisure; when he found by the test of nitrous gas that the air in the bottle contained as large a proportion of oxygen, as common air. He threw melted nitre, both in mass and powder, upon the surface of the lava. The salt fused by the heat, but there was no deflagration to indicate the presence of combustible matter. On making the experiment on a portion of lava taken up in the ladle, it appeared that the brightening of the fused nitre, was partly owing to the peroxidizement of the protoxide of iron; and to the combination of the potash of the nitre, with the earths of the lava, for the spot covered by the melted nitre was changed in colour from an olive to a brown. This conclusion was confirmed by finding that chlorate of potash thrown upon the lava did not increase its degree of ignition so much as nitre; but when a stick of wood was made to communicate a little carbonaceous matter to the lava, it glowed with great brilliancy when nitre or chlorate of potash was projected upon its surface.

When some fused lava was thrown into water, and a glass bottle filled with water was inverted over it, only a very minute quantity of gas was disengaged, which proved on analysis to be common air a little less pure than what is obtained from common water by boiling.

A wire of copper $\frac{1}{20}$ of an inch in diameter, and a wire of silver $\frac{1}{30}$, introduced into the lava near its source, instantly melted; but an iron rod $\frac{1}{4}$ of an inch, with a piece of iron wire about $\frac{1}{30}$, were held for five minutes in the eddy of the stream without

fusion, nor did they produce any smell of sulphuretted hydrogen when acted on by muriatic acid, a proof that no sulphur was present in the lava.

A tin plate funnel filled with cold water, was held in the fumes that issued with such violence from the aperture. Liquid muriatic acid was condensed upon its surface. When the same funnel was held in the white fumes above the lava where it entered the bridge, no fluid was precipitated upon it, but it became coated with a white powder which proved to be common salt, absolutely pure.

A bottle of water holding about three quarters of a pint, with a long narrow neck, was emptied immediately in the aperture from which the vapours issued that pressed out the lava. The neck of the bottle was immediately closed. The air which it contained, being tested by potash-water indicated no carbonic acid gas, but consisted of 91 azote, and 9 oxygen. There was not the least smell of sulphurous acid in the vapour from the aperture, nor were the fumes of muriatic acid so strong as to be unpleasant; but the last quarter of an hour that Sir H. was engaged in these experiments, the wind changed and blew the smoke from the crater upon the spot where he was standing, when the sulphurous acid gas in the fumes were found so highly irritating to the organs of respiration, as to oblige him to descend. Nor was the effect on his lungs transient, for a violent catarrhal indisposition ensued, which prevented him from ascending the mountain for a month.

On the 6th January he made another visit to Vesuvius, and found the appearance of the lava

considerably changed. The mouth (*bocca*) from which it had issued on the 5th December was now closed, and the current flowed silently from a chasm in the cooled lava about 300 feet lower down. The heat was evidently less intense. He repeated his experiments with nitre with the same results, and exposed pure silver and platinum to the fused lava; when the metals were not tarnished. The rocks near the ancient *bocca* were entirely covered with white, yellow, and reddish saline substances, consisting of common salt in great excess, with much muriate of iron, and some sulphate of soda, along with a small quantity of sulphate or muriate of potash, and a minute trace of oxide of copper. There was one specimen of large saline crystals in a cavity, which had a slight tint of purple. These were common salt, with a slight portion of muriate of cobalt.

On the 26th January the lava was seen nearly white hot through a chasm, near the place where it flowed from the mountain. He threw nitre upon it in large quantities through this chasm, but there was no more increase of ignition than when the experiment was made on lava exposed to the free air. The appearance of the sublimations was now considerably changed; those near the aperture were coloured green and blue by salts of copper; but there was still a great quantity of muriate of iron. On the 5th December the sublimate of the lava was pure chloride of sodium (common salt); in the sublimate of January 6, there was sulphate of soda with indications of sulphate of potash. In the sublimates collected on the 26th, the sulphate of soda was in much larger quantities, as well as the potash

salt. From the 5th December to the 20th February the lava flowed in larger or smaller quantities, so that at night a stream of ignited matter was always visible, more or less interrupted by cooled lava. It changed its direction according to the obstacles it encountered ; never extending apparently so much as a mile from its source. During the whole of this time, the craters, two in number, were in activity ; the large one throwing up showers of ignited ashes and stones to a height of from 200 or 300 feet; the smaller one projecting steam with great violence. Whenever the crater could be approached, it was found to be coated with saline incrustations ; and the walk to the edge of the small crater on the 6th January lay through a mass of loose saline matter principally common salt coloured by muriate of iron, in which the feet sunk to some depth. It was easy even at a great distance to distinguish between the steam disengaged by the one crater, and the earthy matter thrown up by the other ; for the steam appeared white in the day, and formed perfectly white clouds, which reflected the morning and evening light, of the purest tints of red and orange ; while the earthy matter appeared always as a black smoke, forming black clouds ; and in the night it was highly luminous at the moment of the explosion.

On the 20th February, the small crater which had been disengaging steam and elastic matter, began to throw out showers of stones. On the night of the 23d, after an explosion which shook the windows of Sir Humphrey's bed-room at Naples, a column of ignited matter was seen ascending from

Vesuvius to a height at least equal to that of the mountain from its base, which illuminated the whole horizon with volcanic light, both direct, and reflected from the clouds above the column of ignited matter. On observing the lava, it appeared at its origin much broader and more vivid; and it was evident that a fresh stream had broken out to the right of the former one. When he visited the mountain on the morning of the 24th, he could not ascend to the top which was covered with clouds, nor could he examine the orifice from which the lava issued; but near the termination of the stream it was from 50 to 100 feet broad. The saline matters condensed on some of the masses of scoria, were of the same nature in their constituent parts, as those of the lava of the 26th January, but with a larger proportion of sulphate of soda, and a smaller proportion of muriate of iron. The dense white smoke emitted in immense columns by the lava during the whole of its course, was most probably produced by the same substances.

In May, 1814, flame and steam issued from the bottom of the funnel-formed crater; along with fumes of sulphurous and muriatic acids. There was no indication of carbonaceous matter from the colour of the smoke; nor was any deposited upon the yellow and white saline matter surrounding the crater, which was principally sulphate and muriate of soda, with muriate of iron, and occasionally muriate of ammonia.

In March 1815, the crater presented very different appearances; there was no lava aperture. The volcano remained quiet for minutes together, and

then burst out into explosions with considerable violence, with the ejection of fluid lava and ignited stones to the height of many hundred feet in the air.

These eruptions were preceded by subterraneous thunder, apparently coming from a great distance, and lasting sometimes for a minute. During the four times that Sir Humphrey was upon the crater in the month of March, he had at last learned to estimate the violence of the eruption from the nature of the sound; a considerable explosion being betokened by loud and long continued subterraneous thunder. Before the eruption the crater appeared perfectly tranquil; and its bottom, apparently without an aperture, was covered with ashes. Soon indistinct rumbling sounds were heard as if at a great distance; these gradually approached, till discharges, like artillery, were felt under his feet. The ashes then began to rise and to be thrown out with smoke from the bottom of the crater; and lastly the lava and ignited matter were ejected with a most violent explosion. "I need not say that when I was standing on the edge of the crater witnessing this phenomenon, the wind was blowing strongly from me; without this circumstance, it would have been dangerous to have stood on the edge of the crater; and, whenever from the loudness of the thunder the eruption promised to be violent, I always ran as fast as possible from the seat of danger." *

Immediately after the eruption, the ashes and

* Sir H. Davy.—Phil. Trans. 1828, Part I., p. 248.

stones which rolled down the crater seemed to fill up the aperture, so that it appeared as if the ignited and elastic matter were discharged laterally, when the interior of the crater assumed the same appearance as before.

Having interrogated nature by these admirable experiments and observations, he next proceeds to offer the following judicious remarks on the theory of the phenomena. It appears almost demonstrable, says he, that none of the chemical causes anciently assigned for volcanic fires can be true. Among these, the combustion of mineral coal is one of the most current; but it seems a most inadequate explanation. However large the stratum of pit coal might be, its combustion under the surface could never produce violent and extensive heat; for the production of carbonic acid gas, when there was no free circulation of air, must tend continually to impede the process; and if such a cause existed, carbonaceous matter would certainly be found in the lava, disengaged along with the saline and aqueous products from the *bocca* or crater. In England we have many instances of strata of mineral coal which have been long burning; but the results have been merely baked clay and clay schists, without any thing at all resembling lava.

Were Lemery's old idea correct, that the action of sulphur on iron may be a cause of volcanic fires, sulphate of iron ought to be the great product of the volcano; which is known not to be the case, and the heat produced by the action of sulphur on the common metals, is quite inadequate to account for the appearances.

When it is considered that volcanic fires occur and intermit with all the phenomena that indicate intense chemical action, it seems not unreasonable to refer them to chemical causes. But for phenomena upon such a scale, an immense mass of matter must be in operation, and the products of the volcano, ought to give an idea of the nature of the substances primarily active. Now, what are these products? Mixtures of the earths in an oxidated and fused state, under intense ignition; water and saline substances, such as might be furnished by the sea and air, altered in such a manner, as might be expected from the formation of fixed oxidized matter. But, it may be said if the oxidation of the metals of the earths be the causes of the phenomena, some of those substances ought occasionally to be found in the lava, or the combustion ought to be increased at the moment the materials passed into the atmosphere. To this objection, it may be replied, that the changes which occasion volcanic fires evidently take place in immense subterranean cavities; and that the access of air to the acting substances occurs long before they reach the day.

The ground under the solfaterra is unquestionably hollow; nor is there any reason to doubt of a subterraneous communication between this crater and that of Vesuvius; for whenever Vesuvius is in an active state, the solfaterra is comparatively tranquil. Sir H. examined the *bocca* of the solfaterra on the 21st February, 1820, two days before the activity of Vesuvius was at its height. The columns of steam which usually rise in large quantities when Vesuvius is tranquil, were now scarcely

visible, and a piece of paper thrown into the aperture did not rise again, so that there was every reason to suppose the existence of a descending current of air. The subterraneous thunder heard at such great distances under Vesuvius, is almost a demonstration of the existence of great cavities below, filled with äeriform matter; and the same excavations which in the active state of the volcano throw out immense volumes of steam during so great a length of time, must in all probability, become filled with atmospheric air in its quiet state.

The limestone caverns of Carniola, some of which contain many hundred thousand cubic feet of air, show the vast extent to which subterraneous cavities may exist, even in common rocks; and the deeper the excavation, the denser is the air, and the fitter for combustion.

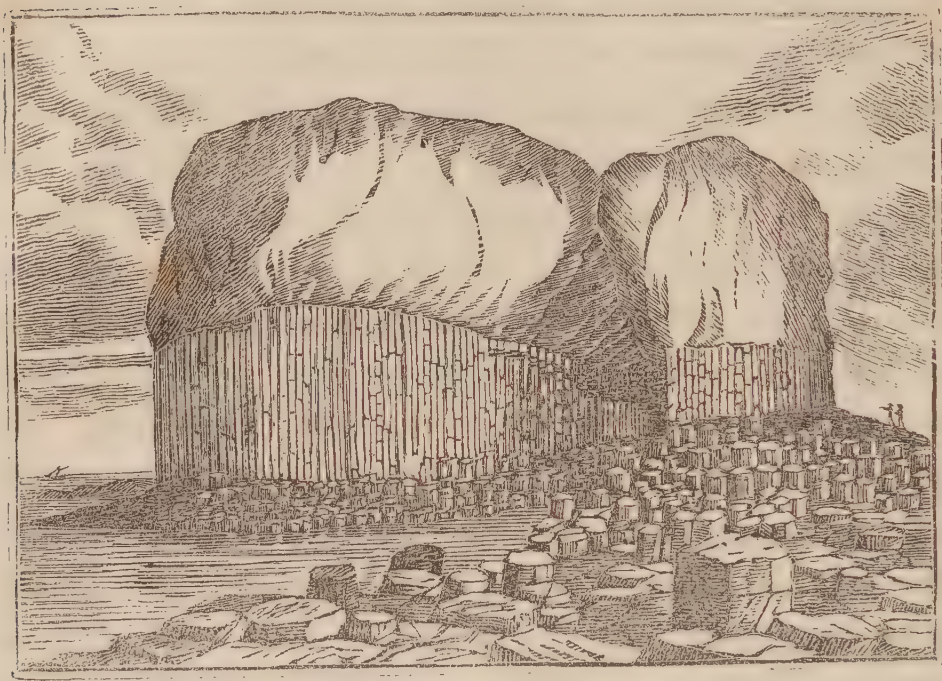
The same circumstance which would enable the alloys of the metals of the earths to produce volcanic phenomena, namely their extreme facility of oxidation, must likewise prevent them from being ever found in a pure combustible state among the products of volcanic eruptions; for before they reach the external surface, they must not only be exposed to the air in the subterranean cavities, but be propelled by steam, a substance equally fit to oxidize them as the air. "Assuming the hypothesis of the existence of such alloys of the metals of the earths as may burn into lava in the interior, the whole phenomena may be easily explained from the action of the air and the water of the sea, on those metals; nor is there any fact, or any of the circumstances which I have mentioned in the pre-

ceding part of this paper, which cannot be easily explained according to that hypothesis. For almost all the volcanoes in the old continent of considerable magnitude are near to, or at no considerable distance from, the sea; and, if it be assumed that the first eruptions are produced by the action of sea water upon the metals of the earths, and that considerable cavities are left by the oxidated metals thrown out as lava, the results of their action are such as might be anticipated; for after the first eruptions, the oxidations which produce the subsequent ones may take place in the caverns below the surface. When the sea is distant, as in the volcanoes of South America, they may be supplied with water from great subterraneous lakes; as Humboldt states that some of them throw up fish.

"On the hypothesis of a chemical cause for volcanic fires, and reasoning from known facts, there appears to me no other adequate source than the oxidation of the metals which form the bases of the earths and alkalis."—*Sir H. Davy, ut supra.*

We must also take into account, considerations derived from thermometrical experiments on the temperature of mines and hot water springs, which show that the interior of the globe possesses a very high temperature. Thus its nucleus would appear to be in fluid ignition; whence the solution of the problem of volcanic fires, becomes still more simple and satisfactory.—*See beginning of Chap.* iii.

§ II. BASALTIC ERUPTION.



Staffa, with Fingal's Cave.

To this head belongs the great family of trap rocks, called by geologists, *unstratified superjacent*, which cover and conceal the secondary beds over immense tracts of country, and which may be regarded as relics of those tremendous volcanic operations, which often shook the old world, while they ushered in, caused, and accompanied the deluge. Nowhere do these eruptive monuments display more instructive and magnificent forms, than in the North of Ireland, and among the Scottish Hebrides, though in one shape or another, they are scattered over all the earth, attesting the universality of submarine fires in the primeval globe. From the manifest tokens of protrusive violence which this formation has every where left among the secondary and tertiary beds of limestone, sandstone, chalk, &c. between and above which it is seen diffused, there can be no doubt that it was projected up through

them, and thrown over them, long after they were deposited, and is therefore clearly of posterior date. For the valuable details which follow, I am principally indebted to Dr. Macculloch and Dr. Boue.

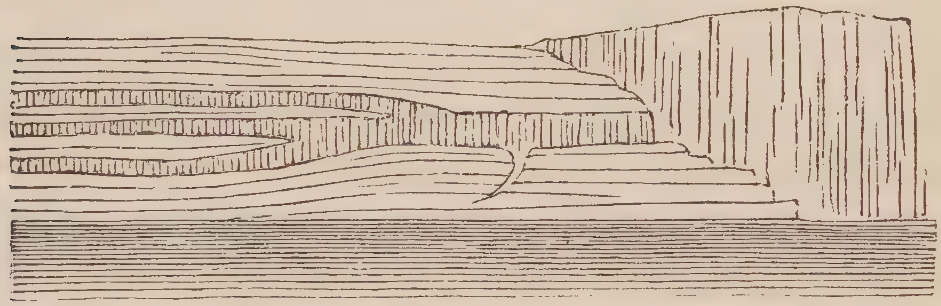
The overlying rocks appear under various aspects, to which mineralogists have given a variety of names; but in truth they all graduate by insensible shades into each other, and hence seem to have had a common origin, as they are in chemical composition nearly the same. They present themselves often in abrupt columnar masses of gigantic dimensions, imparting a black and dismal character to the territory over which they preside. These columns sometimes stand vertically over tremendous precipices, at others, they stretch horizontally along the cliffs, and now and then are twisted and bent into the most curious curvatures. Their blocks are often piled up in rectangular masses, retiring behind each other on the face of a mountain range, as if composing the steps of some colossal stair; whence the generic term trap (stair) was applied to them in Sweden, a name now universally adopted.

This family of rocks, though they want the continuous expanse of the stratified class, and therefore can hardly be ranked among general formations, are yet very extensively distributed over the face of the earth. If Great Britain, for example, in its middle and southern districts, be nearly destitute of them, near the surface, its coal-measures throughout exhibit abundant marks of their presence; and a very large proportion of Scotland lies under their influence.

Here trap sometimes rises into considerable mountains, as in Mull, or forms stupendous mural precipices, as along the western shores of Sky. Occasionally it spreads over the secondary beds in a vast expanded sheet, or shoots out between their layers in a pseudo-stratification; phenomena well exemplified on the whole Antrim coast, from Larne to the Giant's-Causeway. The basaltic effusions are superposited on formations belonging to every geological age, from granite and gneiss to tertiary strata. In Auvergne they are observed reposing on the latest mineral beds, the freshwater limestone; near Annaberg in Saxony, they lie over diluvial land; and in the Vivarais, at the summit of the Coirons, M. Beudant discovered them resting on strata, which contain land-shells (cyclostoma elegans), whose analogues still live in the same country. Nowhere have they been found covered with other mineral beds; and therefore we are justified in regarding the greater part of them as of posterior origin. On the other hand, the appearance of the fragments of these rocks in the lowest sandstone conglomerate, proves that some trap formations also existed before the deposition of the secondary strata.

Granite is sometimes penetrated with veins of trap as at the Cape of Good Hope, where numerous veins of basalt pervade it, which vary in diameter from an inch to ten feet, and branch off in as many directions, as granite veins do in gneiss, but more frequently it is surmounted by coulées of it. Among stratified rocks, both medial and supermedial, it is found in broad masses, as well as in

veins; the former of which run sometimes parallel to the strata for a certain way, then break through into a superjacent plane in which they proceed as before. Irregular masses of trap are seen lying beneath the stratified rocks in some places, from which veins shoot up to the surface, or run in other directions.



Pseudo-stratification of a basaltic vein, injected between beds of sandstone on the east coast of Trotternish. The apparent stratum of trap changes its line of direction, passing up through the planes between which it had formerly spread, and then holding a similar course between others.—*Macculloch's Western Isles.*

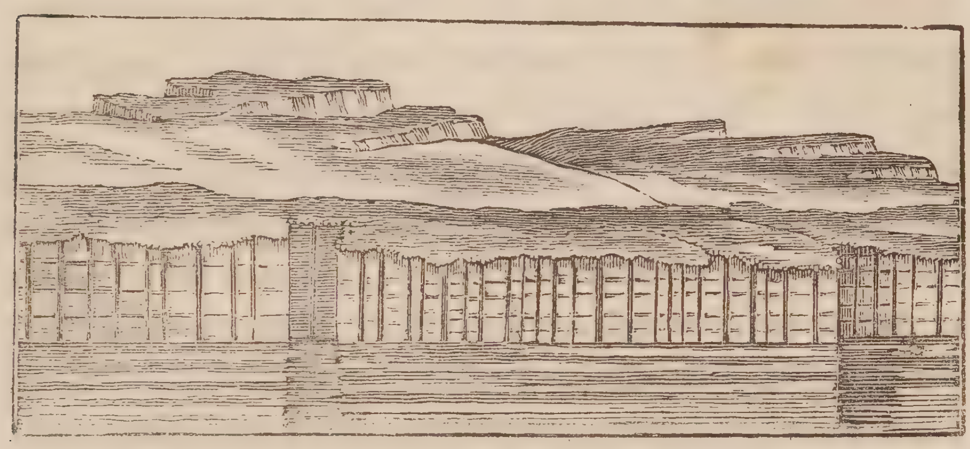
Large beds of trap are often subdivided into prismatic or cubical blocks, which get rounded by the weather into forms hardly distinguishable by the eye from granite. But the traps more usually affect the prismatic figure, a tendency first displayed by vertical lines, which graduate into distinct columnar fissures. The effect of architectural regularity is produced when prisms are crossed by horizontal bands rectangularly, an arrangement conspicuous in Staffa, (see figure at the commencement of this section). The prisms differ in form, and vary in the number of sides from three to twelve, their most usual number being five or six. Their diameters are from an inch to nine feet; and their lengths from a foot to upwards of three hundred; in which space, there are often

transverse fissures constituting natural joints, either oblique or at right angles, to the axis.

This columnar structure is not restricted to basalt; it appears in syenite and claystone in Ailsa, Rum, and Arran; in augite rock in Sky; in porphyry in Arran and Egg, and in greenstone in several localities. The predominant substance in the members of the trap family, is a simple rock, of which indurated clay or wacke may stand at one end of the range, and compact felspar at the other; the intermediate body being claystone and clinkstone. In some cases, the simple rock composes the whole mass; in others, it is mixed with other minerals in various modes and proportions; producing great diversities in the external aspect, without any essential difference in the fundamental nature of the compound. Hornblende is the most common crystalline ingredient of these overlying rocks; and it gives character to three of the leading members of the family, basalt, greenstone, and syenite; in each of which the basis of claystone, clinkstone, or common felspar is united to it. Those rocks in which any of these three bases has a pale-white, yellowish, or reddish hue, are ranked as syenites; and those where it is gray, greenish, or dark-coloured are greenstones. The latter has, moreover, a larger proportion of hornblende than the former. Augite and hyperstene are also two minerals which enter largely into these unstratified rocks, and communicate in each case very peculiar characters.

The most interesting feature of the trap forma-

tion is to be found in the veins of it, which pass through the subjacent or surrounding strata. Perhaps the most remarkable example of these veins is that described by Dr. Macculloch as occurring in Strathaird on the coast of Sky. They traverse in



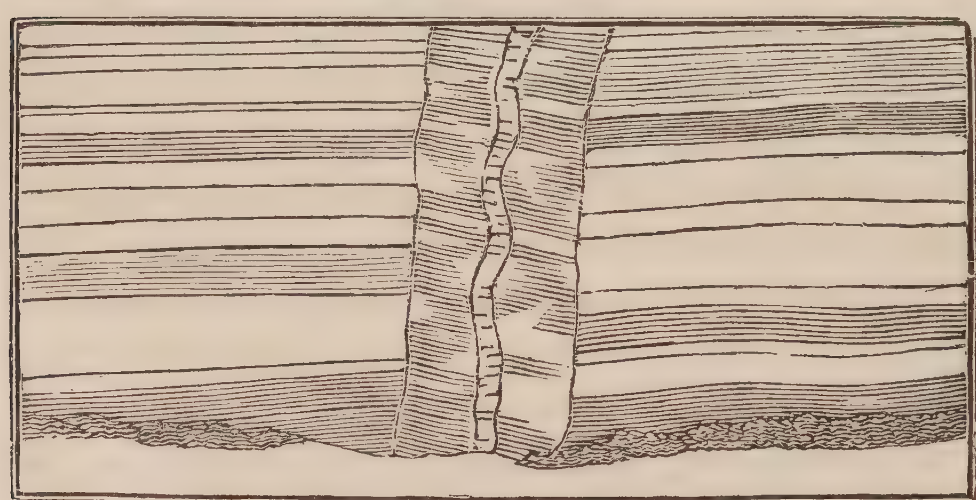
Basaltic veins descending through Sandstone from a superjacent coulée in Strathaird.

nearly a vertical direction, and parallel to each other, the sandstone strata of the cliffs; being so numerous in many places, as nearly to equal, when collectively taken, the mass of the stratified rock itself. Thus 6 or 8 are sometimes observed within the space of 150 feet; and their aggregate magnitude is apparently 60 or 70 feet. The veins do not vary in size through the visible part of their course, nor do they throw out ramifications; their average breadth being 10 feet, though they vary from 5 to 20.

The basalts of an earthy fracture are liable to decomposition by the weather, while the vitreous traps are very durable. In the instance of Strathaird, they seem to decay very fast, and occasion caves and fissures in the sandstone walls. At the spar cave, this wasting effect of the sea and air has corroded the basalt to a depth of 250 feet from the external

cliff. The sandstone partitions that remain, look like terminal abutments, and when cut off behind by similar corrosion, they seem to stand forth in square pillars of masonry.

In one of these great veins, another smaller one is seen passing through it. They all seem to disappear in the superincumbent mass of trap; suggesting the idea, that they penetrated downwards through the unindurated sand beds, from a stream of lava effused above. What gives probability to this opinion, is that the strata remain here quite undisturbed, though they are very liable to disorder from venous intrusions. The sandstone is much harder on the façade crossed by the basalt than elsewhere.



The above figure represents a trap vein, passing perpendicularly through the calcareous sandstone of Strathaird, and again pierced nearly in the line of its axis, by a second smaller vein of basalt, singularly undulated; somewhat like the zigzag line of an electric spark in the atmosphere.

Among the limestone beds of Borrereg an instructive phenomenon occurs. A bed of basalt after flowing extensively in a parallel course among the strata of limestone, makes a sudden flexure into the

oblique position, which shortly becoming vertical, runs away beyond reach of examination in the capricious manner of a trap vein, having in its progress intersected at right angles in one place, those strata to which it lay parallel in another.

The last trap vein deserving specific notice in the Strathaird district, is one found near Loch Oransa, remarkable for the mixture which it presents within itself of all the ordinary varieties of trap; being a fine grained basalt, at the edge, and passing by degrees into greenstone, porphyry, and amygdaloid.

Trap formations like the common volcanic eruptions, have a tendency to recur in the same spot. The alternations found in Canna prove that the several formations visible, there at least, are as distinct in time, as they are in place; since lapse of time is evidently implied in the formation of conglomerate rocks. Here we see rolled masses of basalt aggregated into a *breccia*, which is again covered by a fresh bed of basalt. In the same island, cavities have been observed in the trap rocks exactly similar to those included in the scoriæ of volcanoes, or in cellular lavas. Cells of the same kind occur abundantly in Mull, in the trap near Oban, and they are particularly conspicuous in some parts of the little Cumbray. Such analogies complete the chain, which links the trap formation to visible volcanic products.

The overlying rocks occupy a large portion of the Hebrides. They form the mountain masses of Cuchullin, and the vast cliffs of nearly the whole coast of the large island of Sky. Rum, Egg, Canna, and Mull are nearly in the same predicament. The southern half of Arran is also basaltic; not to mention many partial

formations of the same rock among the other isles. A juster idea of the amount of these projected rocks may however be had from a survey of the great mountain masses which they form in Scotland. The following consist of trap overlying red sandstone:

Dunsinnan hill 1012 feet; Kinnoul hill 632. The chain of the Ochill hills is similar. Here are Bencleugh 2200 feet high, Dalmyatt 2500, Alva hill 1600.

Among the Pentlands; Logan Househill 1700; Caernethy 1500; Kirklow hill 1120; Castlelaw 1390; Kirkyetten 1500; Dalmahoy 680.

Trap elevations near Edinburgh: Braid 480; Salisbury craig 550; Arthur seat 800; Corstorphine hill 470; Castle rock of Edinburgh 335; North Berwick law 940; Taprain law 700.

In the Clyde district: Tinto 2306; Eildon 1360; Campsie 1500; Neilston hill 820; Mistylaw 1240; Castle rock Dumbarton 500; Garroch head island of Bute 700. The highest points of the southern trap hills of Arran and Rasay, are 1000 feet; Cuchullin chain (hyperstene rocks) Sky, 2000; Benmore and Ben y Chat in Mull; the first 3097, the second 2294; Basaltic cone of Lamlash isle 1009; Duncan hill in Rasay about 1500; Storr in Trotternish in the isle of Sky about 2000; Oreval and Benmore, isle of Rum, near 2000; Isle of Canna 800; Scuir of Egg, a beautiful pitchstone porphyry, 1339; northern district of Mull about 1400; district of Gribon in that island 2000; the steep escarpments of the same 1000; Isle of Gometra 800; Isle of Ulva 1300; Isle of Kerrera, in centre, 1200. Combining the extent with the altitude of these mountain masses, we may conceive what enormous convulsions must have accompanied their eruption under the surface of the primeval ocean.

What a vast body of lava must have been ejected to cover an island like Sky, 50 miles long and 20 broad, with coulées in many places 1000 feet deep! The basaltic mantle of the island of Mull is in like manner enormous; and from these two central foci the antique lava seems to have spread over the whole district of the trap isles; of which only small fragments are exposed to view, the great portion being now engulphed in the deep; forming dark basaltic caves, and submarine causeways.

The basaltic mountains differ much in shape. They sometimes appear in massive, irregular groups of angular rocks; as in the

vicinity of Achnacraig in Mull. But most commonly they present a series of terraces placed one above another, capped by slightly rounded surfaces, or in small peaks or detached cones, having a pointed or rounded aspect. Occasionally they compose small mounds flattened on the top, like Macleod's tables in Sky. The ordinary altitude of the terraces is from 20 to 80 feet, and their slope depends partly on the greater or less degradation which the rocks have undergone, and on the nature of the constituent beds. Now and then pretty gentle declivities covered with turf are observed between the precipices. In this way, a trap mountain may consist of two or three vertical sections, joined by inclined planes; a character which serves to distinguish these masses from the primitive and secondary mountains, and to mark their mode of deposition. At other times, the cliffs run nearly straight down from top to bottom. Thus the summits of Storr in Trotternish are cut almost vertically on the eastern side into a façade of nearly 500 feet, presenting detached rocks which by their square or pointed forms, resemble at a distance, castles, towers and spires.

The inclination of the basaltic beds naturally depends on the surface on which they repose; thus in Trotternish, the position of the subjacent gryphite limestone, gives them an inclination to the west, in the isle of Egg they incline to the south, in Staffa they slope down to the east at an angle of 9°, while they lie almost horizontally over the upright edges of the primitive rocks, or over one another, in Mull and its dependencies.

The Campsie hills form a long ridge of overlying trap in the centre of the Scottish Lowlands. They proceed from west-south-west to east-north-east, beginning in the valley of red sandstone near Dumbarton, and ending in the strath of Stirling. On the north from Drymen to Stirling they are bordered by a nearly flat formation of sandy diluvium; and on the south, by coal-measures which connect the grand coal basins of Forth and Clyde. The greatest length of the ridge is about 22 miles, and its average breadth 10, having a surface finely waved with undulations running from south to north. The eminences are in general rounded and have their convex parts turned to the west. On the east, the ridge slopes down in a plane inclined at an angle of 20° or 30°. The summits are in general 1200 or 1500 feet high; but the Meikle-Ben rises to 1800 feet, and gives origin to the rivers Carron and

Endrick; which run to opposite seas. The tops exhibit small escarpments, or steep cliffs on the western side, as do the trap hills in general of the great valley of Scotland, with an occasional display of irregular prismatic colonnades. On the sides of the transverse valleys of Campsie and Fintry, pretty extensive sections of the superposition of several basaltic beds on one another appear, similar to what forms so picturesque an object above Kilpatrick on the north banks of the Clyde, near Dumbarton.

We are indebted to Dr. Berger and the Rev. W. Conybeare for a very interesting account of the basaltic area of the north of Ireland, presenting facts demonstrative of its igneous origin, and the extensive convulsions which must have attended its eruption.

The opposite points of Scotland and Ireland on the Antrim coast, correspond exactly in geological structure. The Mull of Cantyre which faces Tor Point resumes the chain of mica slate which was there broken off. The Cantyre hills are connected with the Grampians, a chain strikingly similar to the mica-slate mountain range of the county Londonderry, which is succeeded on the south by a conglomerate, perfectly resembling that, which is so well known as skirting the Grampians on their southern border.

Of the basaltic group of hills in Ireland, Knocklead in the northern extremity of the eastern chain offers the highest summit, rising 1820 feet above the level of the sea; but its basis is occupied to the height of 500 feet by primitive rocks, leaving 1320 feet for the thickness of the overlying strata. Divis hill, near the southern extremity of the chain, is wholly composed of these strata, and attains an elevation of 1475 feet above the level of the sea. Cragnashoack at the southern extremity of the western chain has a height of 1864 feet. The basaltic covering seems to acquire its greatest thickness on the north, where the basaltic cap of Benyavenagh,

the most northern summit of the western chain, measures more than 900 feet. The average depth of the basaltic superstratum may be safely estimated at 545 feet, and its superficial extent at the prodigious area of 800 square miles, a solid mass of magnificent dimensions.

From the absence in Scotland of the chalk formation the trap lies there in immediate contact with secondary sandstone for the most part, but in Ireland it has substrata of chalk, and other members of the English secondary formations. The chalk in Ireland does not average in thickness above 200 feet, while in England its mean value is 800. It agrees exactly with the lower beds of the English, and consequently of the French chalk, which are distinguished from the higher beds of the same formation, by their greater consolidation. It is impossible for any two portions of the same formation to be more entirely identified, by every external character, and by the fossils and organic remains contained in them, than are these Irish beds, with the English beds in the isles of Wight and Purbeck. In both localities the lower beds are destitute of flints, which the upper contain in abundance; and beneath both of them, the green sand is found, called Mulatto in Ireland. But the numerous beds of coarse calcareous oolites, which in England succeed this green sandstone, are entirely wanting in Ireland, and the mulatto reposes immediately on the lias limestone. This again rests, as in England, on beds of red and variegated marl, containing gypsum, and is further distinguished by numerous salt springs. Under the marl, lies a thick deposit of red and variegated sandstone containing clay galls. These four formations, which

together with the basalt, constitute the whole mass of the mountains associated with the eruptive class, cannot be estimated as possessing a less average thickness than from 800 to 1000 feet. This whole system of beds, at its north-eastern and south-western extremities, appears to repose on the coal formation, and its associated limestone; which in their turn repose on primitive rocks. The proofs which the deep valleys, separating the detached eminences characteristic of the basaltic system, afford of their formation by diluvial action, excavating portions of the solid strata, where no rivers run, are complete, and have been ably illustrated by Dr. Richardson in the Appendix to the Statistical Survey of Antrim. Rolled fragments of primitive rocks are often found on the summits of high basaltic ridges which are at present cut off from all communication with the primitive districts, by numerous intervening valleys; indicating at once the state which preceded or constituted the deluge, and the ravages of its retiring torrents.

The chalk stratum is frequently traversed by basaltic dykes, and often exhibits a remarkable alteration near the point of contact. In such cases, the change sometimes extends 8 or 10 feet from the wall of the dyke, being greatest where in contact with it, and thence gradually passing into the ordinary appearance. The extreme alteration presents crystalline flakes; then a saccharine grain, lastly a porcellanous density; and the altered chalk emits a vivid phosphorescence when moderately heated. In the insulated mass of secondary strata which cap the primitive mass of Slieve Gallion

(on the south of the great valley of denudation, through which the Mayola flows,) the chalk appears underneath the basalt, and there it attains its greatest elevation, being quarried at the very considerable height of 1460 feet above the level of the sea. The deposit is however thin, and the strata much split.

The following section of the cliffs near the Causeway, shows the order of superposition of the different trap rocks.

		Feet
1.	Basalt rudely columnar,	60
2.	Red ochre or bole,	9
3.	Basalt irregularly prismatic,	60
4.	Columnar basalt,	7
5.	Intermediate between bole and basalt,	8
6.	Coarsely columnar basalt,	10
7.	Columnar basalt, the upper range of pillars at Bengore head,	54
8.	Irregularly prismatic basalt. In this bed the wacke and wood coal of Port Noffer lie,	54
9.	Columnar basalt, the stratum which forms the Causeway by its intersection with the sea line,	44
10.	Bole or red ochre,	22
11. 12. 13.	Tabular basalt divided by thin seams of bole,	80
14. 15. 16.	Tabular basalt occasionally containing zeolite,	80

The tabular basalt is the prevailing rock of the trap district, occupying at least nine-tenths of its whole area. It is disposed in beds of considerable thickness. The strata of columnar basalt seem to occur almost exclusively towards the northern boundary of the basaltic area. The pillars are composed of the most compact and homogeneous variety of basalt, containing a small quantity of steatite occasionally imbedded in its mass, and possessing the property of being more or less sonorous when struck with the

hammer. These columns appear in a great many localities besides that of the Giant's Causeway.

The following remarks on basaltic formations by the Rev. W. Conybeare form a note to his valuable paper on the North-East of Ireland in the 3d volume of the Geological Transactions.

While describing the striking appearances presented by Kenbaan cliffs, I cannot forbear to declare the conviction which this spot first impressed upon my mind, and to express my full assent to the arguments of those who maintain the igneous origin of such formations.

I would observe then that this formation is distinguished by characters so directly opposed to those which all rocks undoubtedly of aqueous origin possess, that no hypothesis which ascribes both to a common origin, can be otherwise than contradictory, and at variance with itself. For,

1. Of all other formations, the least ancient are the least elevated; but this the most recent of all, yet rivals the primitive mountains in height.

2. Of all other formations, the degree of consolidation decreases together with their age, their texture passing from crystalline through the several gradations of sub-crystalline, compact, coarse, and lastly earthy; while in this formation, even where it rests on chalk, the crystalline texture of the oldest rocks frequently recurs.

3. Whin dykes, which are indisputably connected with this formation, differ from all other mineral veins, in the circumstance of their traversing all rocks indifferently; while of other veins, particular classes are exclusively associated with particular

rocks. Such being the negative evidence against the Neptunian hypothesis, I proceed to that which is positive in favour of the Volcanists; as,

1. The identity of chemical composition in basalt and lava.

2. The constant occurrence of trap rocks in volcanic districts.

3. The confession of the Wernerians themselves, that the basalt of Auvergne is of igneous origin.

4. The testimony of those best acquainted with districts still exhibiting active volcanoes. Such persons as Dolomieu and Spallanzani, have uniformly maintained the igneous origin of basalt, while those who have contended against it, have generally been unacquainted with countries of this description.

Having thus alluded to, rather than stated, some of the general arguments on which this question appears to me to depend, I return to Kenbaan, where the basalt is seen extending from beneath, as well as overlying, the great mass of chalk, which has at one extremity assumed such a curvature as would naturally result from lateral pressure; and at the other is rent, and shattered in the most extraordinary manner, the basaltic matter insinuating itself into the fissures, and often converting by its contact, chalk into granular marble, while fragments of the chalk of all sizes appear to have been forced upwards, and imbedded in the basaltic rock, having suffered in their superficial parts, where the basalt touches them, a most remarkable change.

It seems impossible to conceive appearances more utterly irreconcilable with the hypothesis, that the basalt was deposited regularly above the chalk from a state of aqueous solution. On the other hand were we to imagine, *a priori*, the phenomena which would probably result from the eruption of a current of ignited lava from beneath the chalk, and its subsequent diffusion over the upper surface of the chalk, while the whole was submerged beneath the sea, and under a considerable pressure, they would exactly accord with those which may actually be observed at Kenbaan.

To the same purpose the change effected by the whin dykes of this district on the rocks they traverse might be cited. Thus we have instances;

1. Of the conversion of old red sandstone into hornstone.—*Geol. Trans. vol. III. p.* 201.

2. Of the conversion of the slate clay of the coal measures into flinty slate, and of the reduction of the coal itself to cinders.—Ibid. pp. 205, 206.

3. Probably also of the conversion of the slate-clay of the lias formation into flinty slate.—p. 213.

4. Of the conversion of chalk in several places into granular marble.—pp. 172, 173.

Hence if it be allowable to speculate on subjects so remote from actual observation, I would infer that the hypothesis which ascribes the formation of the floetz trap rocks to submarine volcanoes, which were active at a very remote period before the seas and continents had assumed their present relative level, is both in itself more consistent, and in its application to the actual phenomena more satisfactory than any other.

It is evident that the basaltic mass of Ulster was accumulated antecedently to the last great convulsion which has modified the surface of our globe, excavating its valleys, and constituting its alluvial deposits.—*Geol. Trans. vol. III. p.* 208.

Professor Buckland in his general outlines of the structure of the Alps, informs us that there are no traces whatever either of trap rocks, or whin dykes, in the Alps of Savoy, Switzerland, or Tyrol, along the entire north side of the great primitive ridge from Mont Blanc to Presburg. But on the south side of it in Tyrol, they occur in considerable force at the Val di Fassa on the east of Botzen, under circumstances of singular resemblance to the trap rocks and whin dykes of Scotland, and the north of Ireland.—*See page* 424.

An excellent mineralogical account of this district has been given by Professor Brocchi of Milan.

The trap protrudes itself through primitive rocks, new red sandstone, and Alpine limestones, both in the form of small dykes and irregular masses; the latter swell into mountains of great elevation at the upper extremity of the Val di Fassa, above Vigo; and in the Sieger Alp close adjoining. They abound in well crystallized minerals, chiefly of the zeolite family, which bear a strong resemblance to those of the neighbourhood of Glasgow. In both countries also the rock itself comes much into contact with, and cuts through strata of the new red sandstone formation. A similar mass of trap occurs also cutting the Alpine limestone of Monte Baldo on the Lago di Garda, where it is remarkable for containing veins and nodules of the green earth of Verona, a substance which probably derives its colour, if not origin, from the decomposition of pyroxene (augite).

Not far south from Fassa on the border of the plain of Lombardy, is a still more extensive formation of trap, which occupies large tracts in the Vicentino, the Monti Berici, and Euganean hills.—*See page* 95.

In these districts, basaltic dykes cut through rocks of all ages, from the mica slate of Recoaro to the *calcaire grossier* (crag limestone) of Monte Bolca, and the Monti Berici; and amorphous masses of trap protrude themselves into and through these same formations, so as to appear, in different points, lying under, over, and alternating with them all. In the Euganean hills, the trap has been said to contain marine shells; and hence an argument has been taken against its igneous origin. But

these remains occur only in a species of basaltic tuff, or regenerated trap, being a conglomerate rock composed of minute fragments of trap, mixed with marine shells of the same character with those that fill the strata of *calcaire grossier*, with which these trap conglomerates alternate. Similar shells are found on the south of Turin at the base of the Sub-Appenines in a breccia composed of fragments of serpentine; and in Hungary also in an analogous breccia composed of fragments of volcanic rocks.

Although no trap rocks occur between the central Alpine ridge, and the great valley of the Danube, yet small portions appear on the north border of this valley at Hoent Wyl, near Schaffhausen, and again at Urach in the Rauche Alp on the north-west of Ulm. Their extent farther north in Saxony and Bohemia, is too notorious to require mention.

The following remarks on the igneous origin of trap are by Dr. Boué.*

The appearance of porphyries in the middle of the coal formation, is particularly interesting, as their origin here has been traced. Near Halle, for instance, some porphyries rise into beautiful domes, like the Puy de Sarcouy in Auvergne, which pass through, or under the coal formation, while others evidently spread over the superjacent sandstone. In the neighbourhood of these protruding masses, great disturbances of the strata occur with alterations of the coaly substance, while anomalous mineral masses appear which pass eventually into sandstone, but are so unlike it at first, as to be called claystone-tuff, lydian stone, jasper, &c. Associated with the above are many true basalts.

The Dr. gives the following characters, as distinctive of igneous rocks ejected under water, from such as have flowed in the open

* Memoirs of Wernerian Society, vol. IV.

air. The submarine lavas, at least those of posterior date to the chalk formation, do not rise into so lofty hills as those which were upheaved into the atmosphere; a difference probably due to the incumbent weight of the ocean. The same pressure has also caused them to ramify more into dykes and smaller veins; and has even flattened the interstitial beds of basalt into a thinner *coulée*. The subaqueous traps are more compact, often intermingled with basaltic tufas, and breccias of a kind of felspar. This conglomerate appearance is hardly ever observed in the atmospheric lavas, since the solid tufas would in their case be discharged from the open volcano. The vitreous character abounds much more in the ignigenous rocks formed in air than in water; while the latter contain many substances resulting from infiltration, or even sublimation, which the former do not possess. Fragments of adjoining strata are often found imbedded in subaqueous lavas; as in the basaltic cone of Dosenberg, near Warburgh, where the protrusive rock contains innumerable pieces of shell limestone. Occasionally masses of clay and sandstone are entangled, as in the clinkstone cone near Banow on the borders of Hungary and Moravia; or indurated like the rock of Portrush near the Giant's Causeway. On the surface of the ground, lavas rarely alter the contiguous rocks, while under aqueous pressure, they generally change, harden, or penetrate them.

We shall conclude the subject of erupted rocks, with the following observations of two eminent geologists.

Mr. de la Beche in his paper "On the Geology of Tor and Babbacombe Bays, Devon," concludes that the appearances of the coast which he has described, point out two distinct geological epochs: 1st, That of the formation of the new red conglomerate, after the limestone and shale had been partially broken up. 2dly, The intrusion of the trap, at a period subsequent to the deposition of the conglomerate and new red sandstone. And besides attributing the disturbed state of this region to the operation of trap, the author is disposed to refer to

the same period and agency, the great dislocations in the oolitic series on the east of the tract which he has described; and to connect with the convulsion by which he supposes that disturbance to have been produced, the greater catastrophe which elevated the chalk of the Isle of Wight,—and even possibly that which threw up the main ridge of the Alps. To the west of Babbacombe the trap is protruded upwards into the overlying argillaceous slate of the carboniferous limestone; the adjacent beds of shale being broken, much contorted, and some portions of them even included in the mass of trap; while the limestone in the upper part of the cliff is also much dislocated. In the inaccessible cliffs near Oddicombe sands, the trap has intruded itself among the limestone and shale, the beds of which are much altered in character, and so broken up near the summit, that they are with difficulty distinguished from each other. The largest mass of trap encloses a large detached portion of the contorted limestone.

Near to a great *fault* at Oddicombe sands, the argillaceous slate is elevated to the top of the cliff, and the adjoining new red conglomerate also rises, as if forced up by the same movement which had affected the slate.

Professor Henslow of Cambridge, has recently described a series of facts observed in the Isle of Anglesea, which prove in the most satisfactory manner, the connexion of veins of trap with very high temperature; since the change produced upon the strata, through which the substances now occupying the veins were injected, has approached so

nearly to fluidity, as to admit of their crystallization, in forms different from any which the components of the rocks, if not thus acted on, would have afforded.

In Mr. Murchison's "Supplementary Remarks"* on the strata of the oolitic series, and the rocks associated with them, in the counties of Sutherland and Ross, and in the Hebrides, we find the following testimony to the eruptive origin of *granite*. In his previous memoir† he stated that wherever the granite rock of the Ord of Caithness comes in contact with the beds of the oolitic series, the latter are compounded into a remarkable breccia; and his subsequent observations have not only fully confirmed the conclusion which he drew from these phenomena: viz. "*that the granite of this coast must have been elevated at a period subsequent to the deposition of the oolitic strata*;" but has also led Professor Sedgwick, as well as himself, to the conviction, that it has been upheaved in a solid form, and that in breaking through these submarine deposits which might not perhaps have been originally in contact, it has so fractured and dislocated their beds as to have prepared them for reconsolidation in the state of a brecciated rock. Hence we might expect, that where the granite disappears, a more full development of the secondary oolitic strata would take place, which actually happens in this district.

The gneiss of the remarkable rocky ridges called the Sutors of Cromarty, is repeatedly traversed by large and small veins of true granite. It is now pretty generally admitted that the granite must

* Geol. Trans. 2d Series, 2d Vol., p. 353. † Ibid. p. 293.

have been in a fluid state at the period when these veins issued from its mass. But the granite which has upheaved and fractured the beds of the oolitic series in Sutherland, could not have been in a fluid state, since it has neither penetrated nor overflowed the contiguous masses of solid breccia. In such situations therefore the disturbing rock was, at the period of its elevation, most probably in a compact and crystalline form; so that, when forced up against the overlying strata, it must have fractured the sandstone, limestone, and shale, thus preparing the materials which when re-cemented (under the ocean) formed the breccia above described. But we have additional evidence of the elevation of the granite *en masse* upon this N.E. coast of Sutherland, where it has not only brecciated the beds of the oolitic series, but has also thrown up the red conglomerate to the summits of many of the mountains, whose bases consist either of granite or of gneiss charged with granitic veins. Thus the old red conglomerate (sandstone) which when undisturbed, passes beneath the oolitic series, and its coal-field of Brora, presents such an anomalous appearance as, without explanation, might lead to the supposition of its being an overlying deposit.

If an adequate cause be required to explain the great upheaving of the granite upon this coast, may we not seek for it in some deeply seated volcanic agency, struggling in vain to expand its forces from beneath the vast mass of primary rocks, of which the mountains in the north-eastern Highlands are composed? No trap is here associated with these rocks, yet eruptive trap or porphyry may have acted beneath the base of the primary mountains, without breaking its way through the superincumbent mass, so as to appear on their surface. On the other hand, trap is developed to a prodigious extent among the *secondary* formations in the Hebrides, as also among the coal-sandstones in the South of Scotland; whence it may be presumed that these latter deposits, owing to their texture and extent, were more

easily traversed, altered, and even obliterated by igneous agency of which they afford so many indications. I regret that my limits will not permit me to enter more at large into Mr. Murchison's excellent views on geological catastrophe.

CHAP. III.—THE CONSTITUTION OF THE PRIMEVAL WORLD,

AND THE REVOLUTIONS WHICH IT UNDERWENT, DEDUCED FROM GEOLOGICAL PHENOMENA, ON PHYSICAL PRINCIPLES.

From the evidence advanced in the preceding chapter it incontestibly follows, that a vast magazine of fire and explosion lies immediately within the crust of our sphere, throughout its whole terraqueous zones.

The subject of the interior temperature of the globe has been lately investigated with all the resources of mathematical analysis by M. Fourier. He considers the heat distributed within the earth as susceptible of three distinct movements.

1. The rays of the sun penetrate the globe, occasioning diurnal and annual variations in its temperatures. These periodical changes cease to be perceptible at a certain distance beneath the surface. Beyond that depth, and even to the greatest accessible excavations, the temperature due to the sun, has long since become fixed and stationary. The whole quantity of solar heat, which regulates the periodical variations, oscillates in the exterior shell of the earth ; descending further within the surface during one portion of the year, and rising up to be dissipated into space, during the opposite or winter season.

2. The temperature of deep excavations constant for any one place, varies for localities more or less distant from the equator, so that the solar heat penetrates further at the equinoctial zones, to re-ascend and be dissipated at the polar regions.

3. We must however consider not only the external calorific focus of heat, but also the action of the proper or intrinsic heat of the globe. If, as the experiments about to be related seem to prove, the temperature of the deep recesses of the earth becomes perceptibly greater in proportion as we recede from the surface, it is impossible to ascribe this increase to the heat of the sun. It can proceed only from a primitive heat with which the earth was endued at its origin, and which may diminish in the course of ages with greater or less celerity by diffusion from the surface.

This hypothesis of an interior central heat has been revived by philosophers from time to time; for it naturally occurs to the mind as the true cause of several great phenomena.

Observations for the Temperature of the Earth.

In the mines of Giro-Magny, three leagues from Befort, M. Gensanne found;

At 333 feet, ...	Temp. 54½° Fahr.
680	62
1016	66½
1429	73

In the mines of Freyberg M. D'Aubuisson found,

External air, . . .	41° Fahr.
In the galleries, . . .	50°
At 528 feet, water pool, . .	52°
858 water of a spring, .	57°
At Junghohebirke, the external thermometer,	32°
At 1040 feet depth, water was .	63°

Observations made by Captain Lean in the mines of Cornwall.

At the surface, in June, ...	59° Fahr.
118 feet deep, ...	64½°
480	68°
840	69½°
1144	79°

December.

At the surface, ...	air,	50°
120	air,	57°
600	air,	66°
— . . .	water,	64°
962	air,	70°
— . . .	water,	74°
1200	air,	78°
— . . .	water,	78°

M. Humboldt obtained analogous results in the mines of Freyberg in 1791, and subsequently in many mines in America.

Several persons have made objections to the above experiments; ascribing the elevation of temperature to the presence of miners, of lamps, &c. M. Arago, in order to obviate this difficulty, examined the water of an Artesian well (a spring gushing up from beneath a deep mineral stratum), and he perceived that its temperature was higher than the water near the surface of the earth. Analogous experiments have been continued, at the request of M. Arago, by M. Berges, officer of engineers, which lead to the same result. This mode of observation seems free from every fallacy.

The preceding facts, and other similar ones, concur to show that the increase is nearly a degree of Fahrenheit for 65 feet. This increase will not be always of the same amount as at the present day; it will diminish progressively, but a great many ages

must elapse before it be reduced to the half of its actual value. The extent of this diffusion of the central heat into the circumference, and of its waste into the celestial spaces, will therefore be proportional to its primitive intensity, and to the conducting quality of the investing materials.

If we apply heat to the flat bottom of a deep vessel (of iron, copper, &c.), which contains several alternate layers of sand, clay, and stony slabs, condensed as in the supermedial strata of England, and covered with water, we shall wait in vain for any distinct manifestation, at the top, of the subjacent fire. In fact, the lowest layer will become compacted by the heat into a schist impervious to liquids, so that the incumbent water will never arrive at the calorific source, and severed by bad conducting matters can never grow appreciably warm. In the great boilers of steam engines, many results to this effect daily occur which form sources of very serious annoyance. Wherever the waters of supply are calcareous, more especially selenitic, they let fall a crust of gypsum on the bottom, which progressively thickens, so as to intercept a large portion of the subjacent heat, and by separating the iron from the water, allows the metal to become ignited and to burn away. Such a deposit has been known to grow several inches thick, with a stony hardness; and till laboriously chiselled off, it has rendered the vessel quite inoperative for raising a due supply of steam.

We have merely to compare these incontestible results of art, to the kindred phenomena of nature, to recognise not merely the analogy, but identity

of operation in the two cases; for difference of magnitude, constitutes no disparity of essence.

In the early epochas of the antediluvian world, soon after the granitic atlas had uplifted the primitive mountains, and before the extensive series of mineral beds, which occupy our second book, were deposited beneath the ocean, its waters resting on the nearly concentric, or slightly broken zones of gneiss and mica slate, necessarily lay in closer proximity with the interior fires, than at any subsequent period. Hence two important consequences: 1. From the thinness of the solid crust, the smallest chink or fissure in it, would be an immediate focus of submarine explosion, accompanied and followed by a commensurate comminution and dispersion of the solid rocks and organic deposits through the agitated waters. 2. The ocean would then attain its maximum temperature; a pitch certainly far higher than at present, yet not incompatible with the vital functions of fish, many of which according to Humboldt can live in water almost boiling hot. Desfontaines found the *sparus* thriving in tepid fountains of 100° Fahr. near the town of Cassa in the kingdom of Tunis.

From the extreme mobility of its molecules, water is the most expeditious conveyer of heat from below upwards; while, from its *non-conducting* quality, it is a most faithful carrier, losing none of it during its ascent. Hence any degree of warmth, however gentle, imparted to the bottom of the oceanic mass, will be transmitted unimpaired to the surface. And again, as water possesses a very high specific heat, one four times

greater than air by weight, so that five gallons of water in cooling only one degree F. can warm by the same quantity 2650 cubic feet of air, being the contents of a chamber about 16 feet square and $10\frac{1}{2}$ feet high; we see what a genial climate would be created over the earth from pole to pole, under such an order of things. Then the intrinsic source of terrestrial heat, having its diffusive energy but slightly obstructed, would be paramount over the solar; so that the position of the sun, relative to the equator, would act a very subordinate part in modifying climate, instead of being its sovereign arbiter, as at the present day. Plants which love a warm but humid atmosphere, like the equisetums, ferns, &c. would multiply and flourish under such circumstances with nearly equal vigour in the Arctic Regions, as under the Line. Hence also the difference of equatorial and polar temperatures would be at first comparatively small, so that a considerable uniformity of vegetation would pervade the most distant zones. We need not, therefore, be surprised at finding the same *Calamites* or gigantic equisetums buried among the coal-measures of New Holland (near Port Jackson), and of England; though nowadays, that plants are subjugated to the undivided empire of the sun, they differ in species with very moderate variations of latitude; and with every change of hemisphere.

The first age of the world then, extending probably through several centuries, fully realized the universal and unfading spring of the poets. Under such fostering powers of vegetation, the coal-measure plants were matured, in countless myriads,

with a rapidity to which modern experience can furnish no parallel. But the tremendous catastrophes of the crust of the earth, that took place soon after this period, of which the dislocations and disruptions of the coal-strata themselves exhibit magnificent memorials, generated a vast quantity of detritus from the older rocks, which at first diffused through a turbid ocean, progressively subsided on its bottom in the chemical order of deposition; constituting beds of conglomerate limestone, red marl, and lias; in variable proportions of thickness and extent according to the nature of the exploded and comminuted rocks. In the secondary formations of Geology, in fact, we see nothing but a repetition of mineral *triads;* shells more or less fractured, covered with a twofold coat, the undermost of sand or sandstone, the uppermost of clay more or less indurated. The tepid ocean-bed vied in fecundity with the glowing soil round its shores, and thus was covered with a thick deposit of shell-fish and their exuviæ. At each rencounter of the water and subjacent explosive metals, these shells would be more or less scattered and broken down, and when tranquillity returned, covered with their siliceous and argillaceous mantles.

The conglomerate limestone, and red marl, are referred by geologists (see Conybeare and Phillips) to the detritus of the primitive and transition rocks; deposits just posterior to the coal formation. It is probable that the submarine disturbances of that particular age were unfavourable to the multiplication of *mollusca.* But a period of repose seems to have followed in which the shells

of the lias were elaborated. These, with a little alumina, are condensed into the lithographic stone, and buried under a loamy compound of sand and clay. We have next the inferior oolite; merely a congeries of pulverised shells; roofed with the cornbrash, &c., and overlaid with the Oxford clay. Then we come to the Coral Rag teeming with vestiges of vitality; inhumed also beneath its sheet of Kimmeridge clay.

When we arrive at the Portland strata, we must consider that a series of most imperfect conductors of caloric, fully half a mile in thickness, had been by this time interposed between the bottom waters of the sea, and the deeper primitive or transition crust, on which they originally reposed.*

* The aggregate thickness of the supermedial and superior mineral strata of England, may be safely estimated at about a mile. The following table is compiled from authentic documents.

		Mean thickness.
Conglomerate limestone (Derbyshire),		300 Feet.
Red marl,		500
Lias,		500
Inferior oolite,		400
Cornbrash including great oolite,		250
Oxford clay,		500
Coral rag,		150
Kimmeridge clay,		150
	2750	
Portland beds,		120
Purbeck beds,		250
Iron sand,		500
Weald clay,		150
Green sand,		30 ?
Chalk marl,		300
Chalk,		800
Plastic clay,		100
London clay,		200
Total thickness,		5200

The climate of the earth should therefore indicate about the Portland era, an abatement of the hypertropical temperature of the first age. "The cycadenoideæ" (fossil plants akin to the cycas family of Malabar, &c.) "says the Rev. Dr. Buckland, render it probable that the climate of these regions, at the time when the oolites were deposited, was of the same warm temperature with that which produces a large proportion of the existing cycadeæ. M. Adolphe Brogniart is also of opinion that it exceeded the temperature of our modern tropics at a still more early period, when it maintained the extraordinary vegetation of the great coal formation; and that it was less than tropical, though warmer than it is at present, in the period to which we owe our tertiary strata. *To this theory I see much reason to incline, and confidently look forward to its future development in the examination of the Flora of the fossil world, which he is now so actively conducting.*" *

Our principles lead irresistibly to the same conclusion, for posterior to the Portland epocha, successive submarine catastrophes of greater or less extent, caused those successive disturbances of the waters, from which the superjacent beds of the iron sand, Weald clay, &c., were deposited up to the

I am well aware that each of the preceding beds does not always lie with all its mass directly above those which precede it in the list; but that they thin off, and wear out in various directions; yet still the average thickness remains substantially correct, in consequence of mutual compensations among the different strata. The argument in the text depends on no such minutiæ of measurement.—*See Conybeare and Phillips passim.*

* Geol. Trans. 2d Series, 2d vol. p. 400.

tertiary formations; the freshwater portions of which were evidently connected with the copious emission of hot springs. The temperature of the surface in these high latitudes of ours, was still genial, though reduced by the progressive operation of the causes already named, and others to be presently described. Finally the great turmoil of the Noachian deluge, placed the terraqueous equilibrium on a more stable basis; introducing at the same time a lower but more regular and settled scale of temperature.

We have hitherto confined our views to the progressive interception of the subjacent heat from the ocean, and thereby from the surface of the earth in proportion as the secondary deposits were thickened after each convulsive catastrophe. But other considerations must now be introduced. While the series of deposits, impervious to water,* were consolidating in alternate beds, and separating the ocean, further and further from the primordial envelope of the interior fires, a great mechanical change was simultaneously taking place on the terraqueous constitution, whose influence in refrigerating climate merits deliberate research. We cannot however consider this change as uniform in its march; but as advancing by successive catastrophes at distant intervals. It is of the nature of volcanic action to intermit and return in temporary crises.† Such periods of violence and repose, cor-

* See pages 202, 252, 263, 265, 270, &c., for notices of the retentive strata in England, which intercept the percolating waters, and throw out the springs at successive levels.

† Volcanoes do not lance out perpetual fires, nor do lavas always

respond to, and are pictured in, the alternate strata of rocky detritus, and of organic exuviæ, which compose the masonry of secondary formations.

Each crisis of chemical deposit, and mechanical transformation, would occasion a sudden and very considerable abatement of terrestrial temperature. But we must present this important subject in a systematic form.

The facts related in the preceding chapters of this work seem fully adequate to establish the four following propositions on sure grounds.

1. That a great portion of the present dry lands, more particularly the secondary strata which are replete with sea shells of the most delicate texture, distributed entire in regular beds, have lain for a long period at the bottom of the primeval ocean.

2. That within the schistose crust of the globe, explosive materials exist, which have given evidence of their convulsive and disruptive powers in all its terraqueous regions and in every age of the world from the protrusion of the primordial dry land, till the present day.

3. That the ocean at whose bottom many of our present earthy strata were deposited, has not been lessened by dissipation of its waters into celes-

flow from them; but they remain for many centuries inactive, and as it were asleep. Vesuvius had lain extinct from time immemorial, when starting all at once from its long lethargy, it suddenly rekindled its fires, under the reign of Titus, and buried the cities of Pompeii, Herculaneum, and Stabii, under its ejected products. It began to slumber once more at the end of the 15th century; so that in 1630, when it resumed an active state, its summit was inhabited, and covered with extensive forests.—The inhabitants of Catania treated as fabulous what history related of the eruptions of Etna, when their city was ravaged, and partially destroyed by the fires of this volcano.—*D'Aubuisson, vol. I. p.* 163.

tial space, or by their absorption into the bowels of the earth.

4. That, therefore, its channel must have been changed by transference of, a great portion at least, of its waters from their ancient to their present basin ; an effect referrible to volcanic agency, which has operated by sinking the old lands, and upheaving the new.

This transflux of the ocean mass could not be effected unquestionably, without the most violent fractures and dislocations of the terrestrial crust. Of the disorders and even metamorphoses of the earth's surface, coincident with these great changes of the sea channel, geology furnishes innumerable proofs, in mountain, valley, and plain. Many of these eruptive phenomena, indicate a succession of catastrophes—an alternation of marine and freshwater floods, over no inconsiderable districts of the globe, at a period anterior to the penal cataclysm described by Moses ; the last and greatest of that convulsive series. This flood was not partial like its predecessors, which left the contemporaneous breeds of animals alive, to be inhumed in the superior beds ; it was manifestly universal, since all the animal remains buried in its detritus, belong to species now extinct, which, however closely allied to our existing genera, left no posterity on the earth. As we rise in the order of mineral superposition, or advance in geological time, we perceive a progressive approximation in the *crasis*, so to speak, as well as in the productions of the earth, to its modern condition in these respects. Thus in the lias and oolites, even up to the chalk, every thing organic

speaks plainly of a fervid climate, actuating both the land and waters, of these high latitudes of ours. But the tertiary strata of England and France bear record to a marked abatement of heat, some time prior to the deluge. The organic exuviæ which they contain, belong to a genial indeed, but not a torrid zone. In addition to the results of the successive interpositions of non-conducting media, between the ocean and its subjacent fires, in lowering the surface temperature of the globe, we must take the following phenomena into account. By each series of explosive dislocations of the terrestrial crust, the area of the "land standing out of the water" would be abridged, that of the sea would be amplified, with a proportionate diminution of its depth; or in other words, the cooling surface would be augmented, at the expense of the heating surface, while the ocean would come to repose as we have seen on a cooler bed, because more distant from the central heat of the earth. These propositions we shall endeavour to place in a clear and certain light by an ample induction of facts.

In a revolving terraqueous sphere, deviating from the equilibrium form of rotation, by its elevated lands and deep ocean beds, at every considerable disruption and comminution of its surface, the gravitating powers will become effective on the shattered shell, and arrange its fragments, so as to make the crust approximate more nearly to the geometrical spheroid. The mountain and tableland masses will thus be strewn over the concave bottom of the seas, and cause a new distribution of the waters round the sphere; in which the area of

the dry land will be diminished proportionally to the extent and duration of the disruptions.

Supposing the earthquakes and consequent comminution of the shell, not partial and successive, but universal and synchronous, then the whole crust of the earth having its cohesion destroyed, for a season, would forthwith obey the gravitating forces on a revolving sphere, would assume the spheroidal figure of rotation, and remain universally circumfused with water, as under the primordial abyss. But a partial and successive series of disruptions of the crust, will cause only a partial approximation to that ultimate figure, accompanied with a transient deluge of greater or less extent over the surface. When the explosive commotions cease, the ocean undulations will subside, the sea will flow back into larger but shallower basins, and the dry land will again appear, furrowed, and strewed over with the detritus of the storm. This view of a diluvial transition, in my apprehension, can hardly be deemed hypothetical, resting as it does on the joint bases of geological facts and physical laws.

The change in the globular figure, and terraqueous distribution, resulting from the fractured strata, may be illustrated by a simple experiment. If we hold a powerful magnet, a little way above a surface of iron filings, strewed upon a table, no change will ensue, because the friction between the solid plane, and the particles, is equivalent to a cohesive force, and prevents them from obeying the magnetical attraction. But if we momentarily suspend the counteracting force of friction by causing the table to vibrate with successive blows,

then the magnetical attraction will become effective, and the iron filings will arrange themselves in beautiful curves, accordant with the known laws of magnetism. In like manner the partial disruptions and tremors of the terrestrial strata, during its transition diluvial state, would permit a corresponding portion of its shattered surface to arrange itself, conformably to the centripetal and centrifugal powers under which it revolves, and cause a partial approximation in its figure, to the oblate spheroid of rotation.

Indeed, without reference to any refined physical law, every one will see how in a *bouleversement* of mountain land, standing out of water, the debris would be distributed over the bottom, so as to spread the waters more widely. In considering the causes of these mighty revolutions, which have subverted the outer frame work of the ancient world, and which seem to have occasioned many unrecorded inundations, before the universal deluge, we must be careful to distinguish between the effect of a moderate expansive force acting within the crust of the earth, and that of a very great one; the former, like the late earthquakes in Chili to be presently described, sufficing merely to raise in an unbroken plain a large tract of land, while the latter would shatter the shell into fragments, and lay them prostrate under the equilibrating powers of gravitation in a revolving sphere. Thus to compare great things with small, a moderate blast of gunpowder, under a stratum of freestone, in a cliff, will be adequate merely to lift it along with its superjacent soil; but a greater explosion will break it into

pieces, and strew the detritus over the surrounding planes and hollows. A few masses may, no doubt, be tossed up to great heights; but the general effect will be a levelling one; as is amply illustrated in the mining operations of a siege, where the massive ramparts of masonry are scattered along the bottom of the fosse. We have therefore every physical reason to conclude that each great antediluvian convulsion of the earth extended the empire of the sea, and abridged the boundaries of the land by a permanent submersion of some of its regions; mechanical effects involving commensurate physical changes of climate; 1. by the thickening deposits of the ocean; 2. by the increase of the cooling or aqueous surface of the globe; and 3. by the decrease of the heating or terrene, as will be fully developed in treating of the deluge in the fifth chapter.

We shall now present a somewhat detailed view of the facts illustrative of the constitution of the antediluvian world, as an abode of vegetable and animal beings; or the physical records of the high temperature which anciently prevailed; and to which, at the different crises of its scale, different genera and species of organic forms are seen to correspond.

M. Adolphe Brogniart, in his treatise on the classification and distribution of fossil plants, comes to the following geological conclusions. 1. That in the formations of coal and anthracite, the vegetables are almost all cryptogamia of the monocotyledinous tribe, such as filices (ferns), equisetums, lycopodiums, marsilea, &c., but the former three

families included arborescent species, which no longer exist, except in the first. He therefore doubts the presence of palms in these strata. 2. That few vegetable remains are to be found in the great interval which separates these beds from the upper deposits, and that those which do occur belong almost wholly to marine plants, or to dicotyledinous trees, which appear to have been transported thither by inundations. 3. That in the higher strata, a great variety of fossil vegetables exist, which for the most part appear to belong to similar kinds of plants, if not in species, at least in genera, to vegetables which still inhabit the hottest regions of the earth, nor is it probable that they have been transported to our colder ones, since there are sometimes found, as in the lignite of Cologne, trunks of palm trees in a vertical position.

Hitherto the chalk, and the calcareous Jura formations, have not afforded any determinable fossil plant. A lycopodite has been found in oolite near Oxford; but in the Alpine limestone we have the wood of dicotyledinous trees, converted into lignite. In the copper mines of Ecaterinbourg, which correspond in locality to the coal formation, there occur very curious specimens of the fossil stems of calamites and stigmaria, enveloped in carbonate of copper.

Vegetable impressions from the coal strata of North America, New Holland (Port Jackson), and various places in Europe, show an analogy between the plants of all the coal measures, whatever distances may exist between them in the present globe.

The figure on the margin, exhibits a fossil impression of a species of polypodium in slate clay (shale) from the coal-measures of Lancashire; considered by Sir James Edward Smith to be the production of a tropical climate.

"Thus," in a recent work of M. Adolphe Brogniart, he says, "every fact observed since the publication of my first essay, on the classification of fossil vegetables, appears to me to confirm the opinion that I then threw out, of the analogy of the Calamites and Equisetums, an analogy since recognised by Sternberg and Bischof. The geological distribution of the species of this family obviously presents a successive suite of characters, from those belonging to the species found in the more ancient formations to those belonging to our existing species."

In the coal-measures and beds of anthracite of the Alps, the Vosges, North America, and even India, we find everywhere true calamites, displaying all the characters which distinguish living Equisetums, and remarkable for their great size. In the more recent formations, we no longer observe these calamites, but genuine equisetums, presenting every character of this family. The

most ancient species, however, which occurs in great abundance and in very good condition in the sandstone accompanying the lignites on the coast of Yorkshire, near Whitby (in a formation equivalent to the lower beds of oolite), differs from all our living equisetums, in having a far taller and thicker stem, and possessing several other characters of less consequence, which give it a peculiar aspect. It is, however, merely a gigantic equisetum.

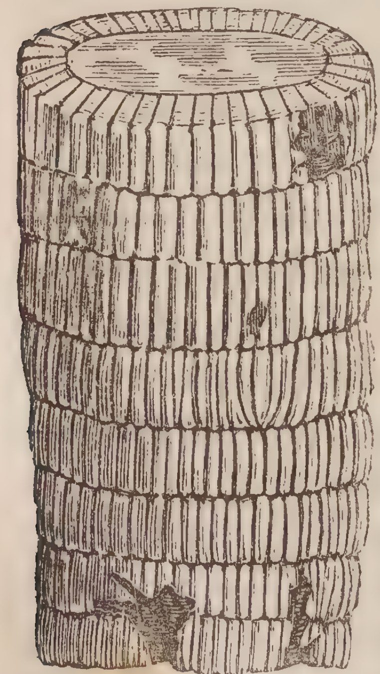
In the tertiary formations, on the contrary, the traces which have been discovered of this genus, indicate plants similar in almost every respect, to those now growing on the surface of the earth.

We perceive, then, that in proportion as the fossils of this family belong to more ancient strata, they recede in their essential characters, from the living vegetables of the same family; being distinguished also by size, which becomes more considerable as the epoch of their interment is more remote.

The remarkable development of these vegetables during the first (or coal-measure) period of vegetation, and their size in the second (or oolitic) period, smaller than before, but still far greater than our existing equisetums, accord with many other facts, furnished by fossil vegetables of other families, to lead us to regard the climate of the earth, at these remote epochas to have been hotter, than the hottest of modern climates; for we have already remarked that the size of the living equisetums increases progressively from the pole to the equator; but even here, never approaches the magnitude of several species of calamites. The

almost constant *habitat* of the vegetables of this family in moist and boggy places (as in peat mosses), is also a circumstance which ought to be particularly borne in mind, as it concurs with many others, to give us just views of the mode of formation of the coal-measures.

Finally the perpendicular posture of the trunks of the *Calamites pachyderma* in the coal-sandstone of Saint Etienne, and of the stems of *Equisetum columnare* in the strata of sandstone above the lias near Whitby, proves that all these vegetables, of entirely different species, lived, though at very different eras, in the same spots in which we find them buried. The differences which we observe in the vegetation of the earth in Europe, at these different epochas, cannot therefore be ascribed to the transport of these vegetables from regions more or less remote from that which we inhabit.*



Calamites approximatus. An antediluvian equisetum (horse-tail) of gigantic growth.

The figure in the margin represents the *Calamites* called *approximatus* by M. A. Brogniart, on account of the proximity of its articulations. It is found in coal-formations as at Newcastle, in the mines of Alais, department of le Gard, and in the copper mines of Ekaterinebourg in Siberia. Of all the plants of this genus, the present is certainly the most distinct, and it has accordingly been re-

* Histoire des Vègetaux Fossiles, 2d Livraison, pp. 111, 112, et 113.

cognised by every author on vegetable fossils.* The confluence of the ribs, or vertical lines, is well shown about the middle of the figure; as also the convex edges of the deep furrows, which they form.

To Dr. Martius, however, the learned Botanical traveller in Brazil, we owe the most detailed information concerning the tropical habitudes of the plants which now lie buried in the coal basins of these northern countries. After making a skilful comparison of these fossils with Brazilian vegetables, he has arrived at very definite results. We may see the type of some vegetable remains in plants which still inhabit the same localities; but these types for the most part, are found only in countries much hotter than where their congenera lie buried; showing that the temperature has been far higher in our latitudes in former times. It was with the express view of clearing up this obscure department of Natural Science, that Dr. Martius directed his attention, in his recent journey through Brazil, towards the investigation of those forms of plants which might be considered as prototypes of the antediluvian vegetables, discovered in our own countries; and he has unquestionably thrown new light on the nature of many fossilized plants.

The *tree-ferns* which constitute so beautiful a feature of the tropical regions, exhibit several characters by which they may be compared with the ancient plants dug up from our coal mines. When Dr. Martius saw the first specimens of *Polypodium corcov-*

* M. Brogniart describes it as follows:—Calamites cortice crassâ, articulationibus approximatis, costisque externe vix ac ne vix quidem distinctis. Articulationes, in caudicibus decorticatis, profunde notatæ, contractæ; costæ convexæ, sæpe confluentes sulcis profundis distinctæ; tuberculi nulli.

adense, so remarkable for the tesselated surface of its *caudex,* he was struck not only with the novelty of the circumstance, but immediately called to mind the figures of certain petrified forms described by Sternberg, under the name of *Lepidodendron;* on comparing which, after he returned, with the stems of eight arborescent species collected in his journey, he found them connected by so intimate an affinity, that he could entertain no doubts of their generic identity, and was convinced in fact that their characters were perfectly accordant.

In their mode of growth the tree ferns are very similar to palms, the evergreen stem of which throws off the fronds, which are inserted into the bark, in the space of about three years, and is then marked with transverse rings, from the insertion of the base of the petiols; they differ however from palms in this respect, that as the base of the petiols is not amplexicaul (embracing the stem), the fronds on falling do not leave annular cicatrices, but of various forms according to the base of the *stipes.*

It is properly remarked by Rhode, in his treatise on the antediluvian genera of plants, that they occur in our coal mines in four different conditions. Some consist of vegetables converted into carbonaceous clay, and still invested with their bark reduced to the state of charcoal; others exhibit impressions of the same plant, with the surface entire, upon clay, slate, or sandstone; others are decorticated vegetables themselves; and lastly others are impressions of these decorticated plants. Before coming to any conclusion therefore with regard to a petrified fern, in order to determine to what sort of cast or petrifaction the specimen under examination is to be referred, it is necessary for this purpose that the characters which we derive from the entire specimen only, and not from its impression, be properly understood, and duly applied.

The *Filicites quadrangulatus,* called *palmacites quadrangulatus* by Schlotheim, Pl. 18. fig. 1, occurs in the older coal formation, at the coal mines of Opperoda in the dukedom of Anhalt, and of Manebach in the dukedom of Gothe. It corresponds with the stem of *Polypodium corcovadense* figured by Nau, pl. 3.

Although we can say nothing with certainty as to the number of species which may have existed of the different genera of ferns, we are yet authorised by many circumstances to infer that the dense

forests of the primitive world, afterwards destroyed by various catastrophes and reduced to coal, have been very abundantly stocked with ferns. Nor is the hypothesis founded upon less powerful and plausible arguments which ranks the genera of this order of plants as among the predominant vegetation of those primeval lands, since they would prepare the soil for the growth of other tribes springing up from their mould, a circumstance noticed by Linnæus. It is not meant however to assert that those primitive forests consisted chiefly of ferns; for the woods of the equinoctial regions, which are pre-eminently rich in ferns, consist of trees much more robust than the ferns which occupy only a secondary rank in them. In like manner we learn from a comparison of the various species of fossil plants, that in the antediluvian woods, the fern stems were interspersed with much larger trees, and on the general destruction of the forests, have been converted together with various kinds of herbaceous plants, into coal, now constituting thinner strata among the carbonaceous remains of other trees. Thus it is ascertained that many fossil plants described by authors under the name of Poacites (Grass-stones) belong to the genus Seleria; others to other genera of Gramineæ and Scitamineæ, occurring in the woods of tropical countries.

Almost all authors agree in representing the family of *palms* as having existed among the first vegetables, and as being frequently found buried along with the other fossil remains. Nor is it to be doubted, says Martius, that their remains, viz. the stems, fronds, and fruits occur in the older coal formation, although they are much less frequent than is commonly believed, the arborescent ferns having been frequently taken for them. A fragment of stem represented by Count Sternberg Pl. 5. fig. 1. exhibits the very peculiar structure of palm wood; and the fruits depicted there, Pl. 7. fig. 12, seem to belong to a species of cocos or areca, shrubs of tropical countries. But that later catastrophes have overwhelmed great multitudes of palms, is proved both by the petrified woods, occellated with fasciculi of fibres, and very easily distinguishable by them, frequently observed in the East Indies and in Europe, and which Dr. Martius has also seen in Brazil; and by the various impressions of fronds in calcareous schistus found in different places in the Tyrol, the south of France, and other countries in the vicinity of the sea, as well as in the continent of Germany. He has in his

collection an excellent specimen of this period, found in the sandstone quarries near Herbipolis, being a piece of stem nearly a foot long, marked with three annuli produced by the fall of the fronds, and with the tubercles arising from the solution of the fasciculi of spiral vessels. The *palmacites obsoletus* of Schlotheim, Pl. 16. fig. 3. and *palmacites annulatus* of the same author, fig. 5, agree in many of their characters with stems of palms, and the latter from its umbonate impressions arranged in rows alternating with transverse striæ or annuli, seems to belong to the aculeate palms. ——— Various genera of *arborescent grasses*, allied to *Bambusia*, seem to have been much more frequent than palms in our antediluvian plains. To these fossil plants the older writers applied the name of *Calamites*. Dr. Martius calls them *Bambusites* or *fossil Bamboos;* now referred to Equisetums by M. A. Brogniart. The *Caciphoræ*, *Dracænæ*, *Pandani*, *Yuccæ* and *Vellosiæ*, constitute another tropical series allied to the palms, which also make their appearance among our primeval plants. The marks by which they may be distinguished, are chiefly connected with the circumstance, that the stems are invested all around with the semi-amplexicaul base of the leaves which remains after the upper parts have fallen off, and hence resemble a surface covered with imbricate scales, spirally arranged in various ways, according to the various disposition of the leaves. It appears that these scales being imbricated upwards are not distinct from each other in their whole extent, and therefore may easily be distinguished from the scales of Filicites, so called. Three species of the genus Yuccites have been dug up from the coal mines of St. Imbert, which are remarkable for the still persistent covering of scales reduced to carbon.——— There exist in our coal mines sufficiently numerous examples of petrified forms, frequently several feet long, remarkable for tubercles or polygonal impressions distinct from each other, and longitudinally disposed in straight lines, separated by parallel grooves or ridges, and marked with a simple cicatrix impressed in the specimen itself, upon the carbonaceous bark, but elevated in the impression or cast. These vegetables belong to the genus of *Cacti*, all shrubs of warm climates. We have for instance some species, says Dr. Martius, such as *Cactus tetragonus*, *pentagonus*, and *hexagonus*, which are furnished with broad and plane surfaces; others as *Cactus cylindricus*, entirely cylindrical, and furnished over their whole surface with

reticulate furrows, among which tubercles project; see plate VI. and its explanation; others as *Cactus repandus* whose obtuse and repand surfaces are much approximated; and lastly others such as all the Opuntiæ, remarkable for their compressed joints, which are plane or sparsely tuberculate. The above different forms while they lay buried among rocks and shale, have been changed in various ways. A great many have been reduced by the extreme pressure into broad flat laminæ longitudinally canaliculate or areolate; a few have preserved their orbiculate form; their dense and fleshy texture having prevented the filling of their trunks with loam, and their subsequent conversion into a stony substance, as we observe to have taken place in other vegetables, and especially the arborescent ferns. For which reason, it would seem that round petrified Cacti have been sometimes taken for calamites. With regard to the surface, in a few specimens, the cortical layer itself remains reduced to the state of coal; exhibiting areolæ formed of lanigerous tubercles, such as we see in Pl. 9, fig. 1. of Sternberg; in others again, and those the more numerous, this layer is loosened from the internal parts of the plant, and is agglutinated to the slate-clay, in such a manner that its internal surface comes into view, of which an example may be seen in Sternberg's Pl. 13. fig. 2; in others again the internal substance itself appears converted into stone, and denuded of its bark. The fourth condition in which *cactites* occur is when the impression of the natural entire surface has been left upon slate-clay; and the fifth when the surface, previously deprived of the cortical layer, has been impressed upon clay or sand. The *cactites giganteus* found in the quarries at St. Imbert, has a diameter of 5 or 6 inches. Dr. Martius describes other 6 fossil species, of which the *tesselatus* belongs rather he thinks to the genus of *opuntiæ*.

A genus of fossils described by Count Sternberg, under the name of *Syringodendron*, agrees in many of its characters with the *Cactites*, nor can it be doubted that it belongs to the succulent or fig tribe of vegetables.

There is a very remarkable fossil, with branches attenuated upwards, and having the whole surface covered with leaf bearing scales, arranged in an imbricated manner, (like slates on a roof) neither referrible to the genus Yucca, nor to that of Cactus, to which Sternberg has given the name of *Lepidodendron* (bark tree)

dichotomum. Dr. Martius is of opinion that this may with propriety be referred to a new genus which he met with in Brazil. The fields of the province of *Minas Geraes*, at a height of 2000 feet and upwards above the level of the sea, and especially the diamond district, afford a genus of the order *Compositæ*, much allied to the *Vernoniæ* of Linnæus and the *Pullalestæ* of Humboldt, which seem to correspond in every character with our petrified plant. He proposes to call it *Lychnophora.* There are several species of them, forming shrubs about the height of a man.

Whoever compares the figures and description of *Lepidodendron dichotomum* with these living plants, in respect to habit, ramifications, and the tesselated work investing the trunk, which in the fossil plants is converted into charcoal, will be convinced by their numerous points of agreement, of the existence of a perfect identity, and be constrained to join in the opinion of Dr. Martius. He describes two fossil Lychnophorites, which are found in quarries at *Sconia* and *Radnits* in Bohemia.

With regard to this plant, as well as the preceding genera, it deserves to be remarked, that like ferns, they are all vegetables furnished with a singular structure of organs subservient to respiration, and highly adapted for inhaling nutritious juices from the atmosphere. It is well known that the *Cacti,* as well as most succulent plants, derive their nourishment more from their relation to the air than to the earth. The Yuccæ and Lychnophoræ which choose for their habitation a dry sandy soil, that has undergone little preparation from the decomposition of previously existing vegetables, were, says the Doctor, peculiarly adapted for clothing a recently formed world, much warmer than the present. By such plants, vegetable matter would rapidly accumulate to the extent that we find in our coal strata. The mixture of plants which in our times inhabit only dry, sandy, or rocky exposed places, and which do not grow in the midst of trees, nor even thrive in their vicinity along with genera like the ferns, which love damp and shady places, merely indicates what the basaltic phenomena attest, that inundations of considerable extent were from time to time thrown over the land, whence the dry and moist tribes of vegetables, would alternately prevail in the same district; besides it is not at all improbable "that those plants, the *Cacti*, *Lychnophoræ*, &c. which we still find occasionally associated with *Agavæ*, *Bromeliæ*,

and arborescent ferns in the tropical regions, being extended to an enormous magnitude by a vigorous vegetative power, formed vast umbrageous woods," affording a suitable retreat to many plants that love marshy and shady situations, such as the Scitamineæ and various tropical genera of grasses and ferns.

"It is only necessary to observe that these petrified vegetables have undoubtedly lived in the same countries in which they are now found, and have not been transported from remote places by floods, and buried in ruins of various kinds. But that those formations to which we give the name of pit-coal, have derived their origin from ages much more remote than those in which the beds of brown-coal (Lignite) were deposited, is also proved by the vegetables which occur in the latter, and which for a great part exhibit leaves, fruits, and woods, of modern plants, and especially native genera of the north of Europe."*

The lignites being, from their geological situation, of much more recent production than the proper coal measures, accord perfectly with the above observations. They occur frequently under trap rocks. The general deluge seems therefore to have been preceded, by several partial inundations, betokening to man the great catastrophe about to destroy his race. These floods would favour the growth of a new set of vegetables, in the districts subject to trap eruptions, and would subsequently sweep them off into the bed of the adjoining sea, whence they emerged after the final cataclysm.

The celebrated Count Sternberg, author of the Botanical and Geognostical Essay on the Flora of the Ancient World, a splendid work on Antediluvian plants, says, "that the vegetation subservient to pit-coal, consisted of several species of large trees, of which I have in my collections trunks 18 inches in diameter. These trees seem all to have belonged to the monocotyledinous or polycotyledinous families. They are palms, bamboos, &c. The vegetation

* Dr. Martius on Antediluvian Plants; Edin. Phil. Journ. vol. XII.

which gave birth to the formation of brown-coal seems to have been that of a great continent; it is also formed of large trees whose texture is still to be discerned in the brown coal; but hitherto I have not been able to discover, either petrified trunks, or impressions of bark so frequent in the mines of pit-coal. Scattered leaves, which without being known to me, appear undoubtedly to belong to dicotyledinous families, are all that I have hitherto discovered.—*Memoires de Museum*, V. 163.

If we examine the fossilised fruits found in the upper strata we shall see that several of them evidently belong to the same family of palms; but one of the most extraordinary facts connected with this subject is, that none of these fruits appear to have grown on the palms with fan-shaped leaves; but on the contrary, that all the fruits that have been correctly delineated by authors, seem referrible to the genera with pinnate (feather-formed) leaves.

There is no doubt, however, that palms with fan shaped leaves covered Europe with their lofty vegetation at this remote period, in regions where no species of these plants could now grow. The opinion of some writers that these vegetables may have been transported from remote climates into the places where they are actually deposited, appears at variance with every fact hitherto observed, and possesses in reality no solid foundation.

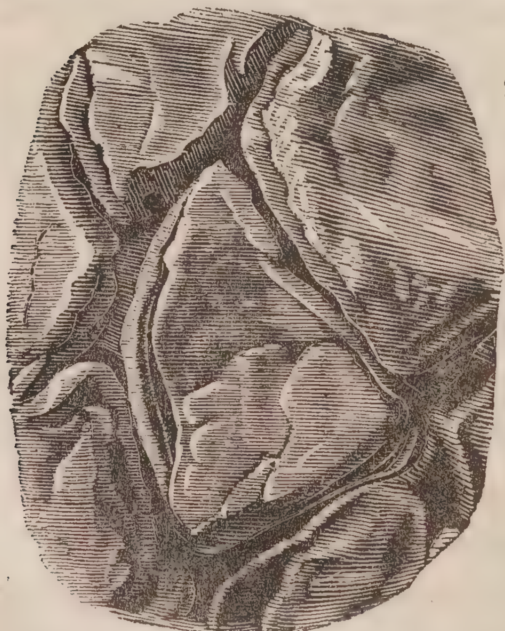
The posture of fossil vegetables in coal mines, the perfect preservation of extremely thin leaves, such as those of the ferns, the entire state of their fronds, which are often extremely large, and above all, the presence, in many of these mines, of vertical trunks of trees rising up through the several strata of rocks that enclose them, are incompatible with the hypothesis of transport.—*Count Sternberg*.

The Rev. Dr. Buckland read last May, to the Geol. Society, a paper already quoted, descriptive of a new family of fossil plants, which occur in the freestone quarries of the Isle of Portland. Their external form approaches to that of the fruit of the pine apple, but is still more like the trunk of a living zamia. These plants supply from the fossil world, a link to fill the distant void which separates the cycadeæ from the nearest existing family the coniferæ. Their occurrence in the Portland oolite adds another to the many facts which indicate the climate of these regions, during the period of the oolitic formations, to have been similar to that of our actual tropics.

"Thus, dispersed through various members of the grand oolite formation or Jura limestone, we have trunks and leaves, and perhaps organs of fructification, that may with much probability be all referred to our new fossil family of cycadeoideæ. We have the trunks in Portland, the leaves at Whitby and in Scania, and both leaves and amenta? at Stonesfield; and though we are as yet without materials to show the specific relations of these parts to one another, we have evidence to prove the duration of one, or both the cognate families of cycadeæ and cycadeoideæ to have extended from nearly the lowest to the uppermost beds of the oolite series."

To the same conclusion, concerning the tropical vegetation of our climates in antediluvian times, Mr. Mantell has brought very decisive support in his able "Illustrations of the Geology of Sussex." "Whether Tilgate Forest," says he, "was an island or a continent may not be determined; but that it was

diversified by hill and valley, and enjoyed a climate of a higher temperature than any part of modern Europe, is more than probable. Several kinds of ferns appear to have constituted the immediate vegetable clothing of the soil; the elegant *hymenopteris psilotoides*, which probably never attained a greater height than 3 or 4 feet, and the beautiful *pecopteris reticulata*, of still smaller growth, being abundant everywhere. It is easy to conceive what would be the appearance of the valleys and plains covered with these plants, from that presented by modern tracts, where the common ferns so generally prevail. But the loftier vegetables were so entirely distinct from any that are now known to exist in European countries, that we seek in vain for any thing at all analogous, without the tropics.



Fossil plant called *Clathrarea*, quasi *Cleithraria*, chink-wise; from the fissures on its surface.

"The forests of *Clathrareæ* (see marginal figure), and Endogenitæ, (the plants of which, like some of the recent arborescent ferns, probably attained a height of 30 or 40 feet,) must have borne a much greater resemblance to those of tropical regions, than to any that now occur in temperate climates. Turtles of various kinds must have been seen on the banks of its rivers or lakes, and groups of enormous crocodiles basking in the fens and shallows. The gigantic *megalosaurus*, and yet more gigantic *igua-*

nodon, to which the groves of palms and arborescent ferns would be mere beds of reeds, must have been of such prodigious magnitude, that the existing animal creation, presents us with no fit objects of comparison. Imagine an animal of the lizard tribe, 3 or 4 times as large as the largest crocodile, having jaws equal in size to the incisors of the rhinoceros, and crested with horns; such a creature must have been the iguanodon."

Professor Kounizin describes in the Isis for 1821, immense beds of fossil wood in several localities of the governments of Novogorod and Twer in the north of Russia, where no such trees are now found to grow. In moist clayey soil, they are sometimes petrified. The oaks not petrified are very tender when first dug up, and may be cleft easily into thin spars, like pinewood; but when dried, they become blacker, and so hard, that the hatchet is notched in cutting them. There are no oaks to be found growing even in any of the contiguous countries, which have been bare and barren from time immemorial. Similar beds of fossil wood occur over the whole of North Russia, on the banks of the Doubna, Kachinka, and Karojincha, as also in the governments of Wologda and Aloncy.

Near Canstand on the river Necker, M. Autenrieth found an entire forest of the trunks of palm-trees buried along with the remains of elephants, of which more than 60 tusks were found, none of them deeper than 20 feet beneath the surface, in an indurated mass of clay, sand, pebbles, and ochre, which had to be blasted by gunpowder to get at the fossils.—*Cuvier, Ossemens Fossiles, I.* 122.

The fossil shells found in the strata of England, France, and the contiguous countries, having for the most part no antitypes alive, except in equatorial regions, harmonise with the preceding details.

It has been said that in the calcareous strata at Grignon near Paris, more genera and species occur than could be found on the whole coasts of France. It is only between the tropics where the ocean contains such a number of mollusca, that sea-grounds can be found as rich in testaceous productions as the bed of Grignon. If we take into account also, that the fossil shells belong mostly to hot climates, we shall conclude that in the latitude of France in that former state of things the climate must have been of a tropical temperature. The nautili spiruli, and many other shells found fossilised in our strata, exist alive only near the equator; a fact which confirms the preceding proposition. The following table exhibits a comparative view of the number of genera and species of animals, heretofore discovered both in the fossil and living state, with the strata in which the fossilised are found.

The polypary family, the first in the list, includes the madrepores, and other worm-like creatures, which construct what are commonly called the coral reefs. In the department of Calvados in France, mineral beds occur of very great extent, composed almost entirely of the debris of polyparies. In other regions still farther to the north, remains of large fossil polyparies exist, whose genera now live only in tropical seas.

General Table of Living and Fossil Genera.

NAMES OF CLASSES, AND NATURAL ORDERS, OR FAMILIES.	NUMBERS OF THE GENERA WHICH ARE FOUND — IN THE			IN THE STRATA			Total of genera.	NUMBERS OF SPECIES		REMARKS.
	Living state.	Living and fossil state.	Fossil state.	Inferior to the chalk.	Of chalk.	Superior to the chalk.		In the living state.	In the fossil state.	
Polyparies, ...	23	30	52	47	19	36	105	527	414	
Stellérides (Starfish),		4			2	4	4	76	4	
Echinides (Sea urchins),	2	6	3	7	8	5	11	95	112	
Annelides, ...		2	1	1	1	2	3	17	29	
Serpulées, ...	2	3	1	3	3	3	6	36	69	
Cirrhippèdes, . . .	8	2		1		2	10	50	17	
Tubicolées, ...	1	3	2			5	6	11	16	
Pholadaires, . . .		2				2	2	12	4	
Bivalve shells, . . .	18	61	24	44	25	51	103	1009	1104	
Univalve shells, . .	33	87	28	27	16	93	148	1945	1544	The remains of birds being very difficult to distinguish, the number of their genera in the fossil state is probably much more considerable.
Genera little known,			4	3	1		4		5	
Crustacea, ...		21	5	5	2	9	28		54	
Fishes, ...		54	6	11	2	55	60		183	
Mammiferous and cetaceous,		24	12			36	36		89	
Birds, ...		3				3	3		3	
Reptiles, ...		4	4	3	2	4	8		23	
Insects, ...		14				14	14			
Vegetables, ...		14	10	12	1	15	24			

This curious table, and its introductory statements, are taken from the article Petrifactions, written by M. Defrance for the *Dictionnaire des Sciences Naturelles*, and published in 1826.

CHAP. IV.—ELEVATION OF SUBMARINE STRATA.

Having endeavoured to solve one enigma of the primeval world, the fervid temperature of even its circumpolar zones, I shall next offer some remarks illustrative of another geological difficulty, the transfer of the ocean from its ancient to its present bed.

Existing phenomena justify us in referring this mighty change to a twofold operation; the elevation of certain submarine strata over an extensive region, and the concomitant disruption and submersion of dry land. The basaltic or trap phenomena, lead to the conclusion that such upheavings and subversions were not confined to one epoch of the antediluvian world, but that coeval with its birth, they pervaded the whole period of its duration. Hence sea-born lands came forth to the day, and primeval plains were engulphed in succession; circumstances fully demonstrated by the dens of antediluvian animals which abound in shell-limestone rocks, and by many other appearances. Such extensive elevations of land, often to vast heights, necessarily involved a corresponding displacement in the bed of the waters; which being of invariable volume must have shifted their position with every change in the form of their basin. The deluge, that universal transflux of the ocean, was the last and greatest of these terraqueous convulsions, and finally gave our spheroid, the more stable equilibrium which it has ever since possessed.*

The nature and causes of that unstable equilibrium, whose traces are still visible in the antediluvian frame-work of the globe, we have endeavoured to explain, and shall add some further remarks in the chapter entitled "Phenomena of the Deluge." Meanwhile I shall prove by decisive evidence, that even under our more settled terra-

* "Neither shall there any more be a flood to destroy the earth." *Genesis* ix. 11.

queous equilibrium, extensive tracts of land have been upheaved or elevated from the waters in post-diluvian times.

In advancing these proofs, I shall commence with the testimony of an intelligent eye-witness to a recent phenomenon of the kind, on no dubious or inconsiderable scale. I allude to the "Account of some Effects of the late Earthquakes in Chili, by Mrs. Maria Graham," published in the first volume of the second series of the Geological Transactions.

The first shock by which the towns of Valparaiso, Melipilla, Quillota, and Casa Blanco were almost destroyed, and Santiago much damaged, was felt at $\frac{1}{4}$ past 10 o'clock in the evening of Tuesday 19th Nov. 1822. It lasted 3 minutes. In a few minutes after the first shock there was another less severe; and from that time, the whole night long, successive shocks were felt, twice in every five minutes, each lasting from a half to a whole minute. On the 20th, 21st, and 22d, the shocks continued. A little before 10 of the latter day, three successive loud explosions were heard, like the sound of heavy artillery, and under which the earth trembled violently. The weather was hot and sunny on one day, and foggy with cold drizzling rain on another. On the 23d and 24th, the earthquakes continued with a mild cloudy sky. From this time till the 18th January, 1823, when Mrs. Graham left that country, continual earthquakes more or less severe, were felt every day; and she has learned that they were very violent in the subsequent July, and had not ceased altogether so late as September.

The sensation experienced during the more violent shocks was that of the earth being suddenly heaved up in a direction from north to south, and then falling down again; a transverse motion also being now and then felt. The tremour between the shocks was shown to be real by the agitation of water in a glass; and during the shocks themselves, water or mercury placed in a glass, was thrown over the edge in every direction. In the house where Mrs. G. resided, the furniture was all displaced with some degree of regularity, so as to range not parallel to the walls which fronted to the north and south, but at a given angle diagonally. The sensation

experienced on board the ships that lay in the harbour of Valparaiso, was as if they were moving very rapidly through the water, and occasionally touching the ground. On the first shock on the night of the 19th Nov., the sea in Valparaiso harbour rose to a great height, and then receded so as to leave the small vessels that were before afloat, dry on the beach; it then returned, but as compared with the level of the land, not to its original level. All this is stated to have happened in the course of a quarter of an hour.

In all the small valleys, the earth of the gardens was rent, and quantities of water and sand were forced up through cracks to the surface. In the alluvial valley of Vina a la Mar, the whole plain was covered with cones of earth about 4 feet high, occasioned by the water and sand which had been forced up through funnel-shaped hollows beneath them; the whole surface being thus reduced to the consistence of a quicksand. At the roots of all the trees between the surrounding earth and the stem, large hollows were seen, into which the hand could be introduced, occasioned by the violence with which the trunks had been lashed to and fro. The bed of the lake of Quintero was full of large cracks, and the alluvial soil on its shore was so divided as to look like a sponge; the level of the lake, which communicates with the sea, had apparently sunk very much.

The promontory of Quintero consists of granite covered by sandy soil. The granite on the beach is intersected by parallel veins, from a line to an inch in thickness; most of which are filled with a white shining matter, but some are only coated with it on their sides, and present hollow fissures. After the earthquake of the 19th the whole rock was found to be rent by sharp recent clefts, very distinguishable from the older ones, but running in the same direction. Many of the larger of these clefts might be traced from the beach to the distance of a mile and a half across the neighbouring promontory, where in some instances the earth parted, and left the stony base of the hill exposed.

On the morning of the 20th, it appeared that the *whole line of coast from north to south, to the distance of above* 100 *miles, had been raised above its former level.* From a small hill above Quintero, Mrs. Graham perceived that an old wreck of a ship

which before could not be approached, was now accessible from the land, although its place on the shore had not been shifted. The alteration of level at Valparaiso was about 3 feet, and some rocks were thus newly exposed, on which the fishermen collected the scallop shell-fish, which was not known to exist there before the earthquake. At Quintero the elevation was about 4 feet. When Mrs. G. went to examine the coast, accompanied by Lord Cochrane, although it was high-water, she found the ancient bed of the sea laid bare and dry, with beds of oysters, muscles, and other shells adhering to the rocks on which they grew, the fish being all dead and exhaling most offensive effluvia. She found good reason to believe that the coast had been raised by earthquakes, at former periods in a similar manner; several ancient lines of beach, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of 50 feet above the sea. The country was in former years visited by earthquakes, the last of any consequence having been 93 years ago.

The shock of the 19th, was felt as far as Lima to the north, by the ships then riding in Callao bay. To the south, it was experienced at least as far as Conception; and to the east, beyond the Andes, at Mendoza and at St. Juan. The distance from Conception to Lima is about 20 degrees of latitude or 1400 miles.

To the above graphic narrative we may add the following particulars inserted by M. Arago in the 27th *volume* of the *Annales de Chimie et de Physique*, p. 380.

On certain spots the ground appears to have experienced during the shock a movement of rotation. The following are the facts on which that marvellous assertion rests,—*Des murs et des maisons, après l'événement étaient tournés en rond.* I shall not translate this novel phenomenon, as M. Arago regrets, that the expression in the original relation, is deficient in precision. At Quintero, ten miles to the north of Concon, at the mouth of the Rio Quillota, are several lofty palms; three of which, after the earthquake, were twisted round each other, like willow wands. The movement of rotation is further proved by the circumstance of each of these trees having swept a small space round about its stem. At Valdivia, in south latitude 39° 59′, only one moderate shock was felt; but at the moment of its occurrence, two volcanoes of the neighbourhood made a sudden eruption with a loud noise, illuminated the whole surrounding country for some seconds, and forthwith returned to their ancient state of tranquillity. On the 27th Nov. eight days after the strong shock, there fell over a great extent of Chili, copious rains accompanied with violent whirlwinds. As rain had never been observed before in the month of November, the earthquake must consequently have introduced some notable modifications into the atmosphere of the country.

The upheaving phenomenon of Chili is merely a miniature type of operations extending through every geological epoch and district of the world. Thus the facts detailed by Signor Brocchi in his *Conchologia Subappenina* concur to show that the whole promontory of Italy has been lifted up in an unbroken mass out of the ocean; for it is all covered with an alluvium evidently of marine origin, over which is spread another coat, the *diluvium* or detritus of the great deluge, common to every region of the earth.

This marine deposit is found not only in many low situations, but it forms a range of hills at the foot of the Appenine. It occurs also in Piedmont, near Parma in Placentia, whence it stretches all

over the north side of this ridge to Otranto: and on the south side, it skirts the elevated land in a similar manner, occurring at Orvieto, Rome, near Terracina, and elsewhere. The same alluvia are to be seen near Vicenza and Verona, or at the foot of the Alps, as well as the Appenines; so that the term Subappenine has not been well chosen.

These beds are nearly horizontal, and consequently unconformable to the inclined calcareous strata of the Appenines on which they lie. The fishes of Monte Bolca belong to the marine alluvial bed. They are found in a marly slate, which does not lie in continuous strata, but in distinct and detached masses among the looser materials. The indurated animal matter, mixed with the including earth, is of a brown colour, and at times so thick as to project from the stone, in a separable state.

In this alluvium of Brocchi, besides the more common marine fossils, the bones of whales and dolphins are found. Even entire skeletons of these animals have been discovered at elevations 1200 feet above the sea. The whale bones are in some places incrusted with oyster shells, and almost uniformly in perfect preservation; showing that they have not been brought from a distance, and that the alluvia in which they lie have not been transported.

The animal terrestrial remains of the upper diluvium are generally found a few feet below the surface, intermixed with the sand or gravel; but as that bed is occasionally absent, they also occur in the marl. They consist of the bones of the hippopotamus, elephant, rhinoceros, mastodon, urus, and elk, together with the horns of stags; to which must be added vegetable remains, consisting of the fragments and trunks of trees, with leaves little altered, freshwater shells, and lastly fragments of travertino or alluvial rocks, and vegetable calcareous incrustations, resembling those which are daily formed by native solutions of carbonate of lime.

In different countries, and in Italy very particularly, it has been observed, that the relative level of the sea and land has suffered

several alterations. The proofs and nature of these are given by Breislak and other writers, who have minutely examined this subject. The present case may be considered an extreme one of that nature, one which shows that the bottom of the sea, together with its unconsolidated alluvia, has been raised above the surface of the water, so as to have become dry land. Thus it is easy to account for the presence of marine remains, as well as for their singularly undisturbed state.

It is equally easy to account for the proximity of the marine and the terrestrial remains, as also for that of the alluvia which repectively enclose each. Whatever cause or causes generated the usual terrestrial diluvia that occur all over the world, these have apparently been deposited, in most cases on naked rock. In this particular one, they have settled on a previous alluvium of a different character; and wherever the two are mixed, we may ascribe this to diluvial currents.

"It now follows," says Dr. Macculloch, "that the elevation of the land of Italy, which is the origin of these phenomena, is to be attributed to the same causes which are now, or have recently been, operating in producing smaller changes in the relative level of the sea and land, and, of course, in elevating the latter. These causes are connected with earthquakes and volcanoes, or are dependant on volcanic action. They are the same that raised Santorini from beneath the ocean, and that have produced the phenomena of the coral islands presently to be described. In the history of these islands, further proofs and confirmations of these views will be found. . . . . That the skeletons of whales should be found at 1200 feet above the level of the sea, is no more surprising than that they should be found at all. This particular fact is, however, important, as showing the vertical extent of this elevation, just as the geography of the marine remains demonstrates that of its superficial one. . . . . . It is probable that at the period at which modern Italy was produced, the whole of the central chain experienced a fresh elevation to the altitude of at least 1200 feet, and over a superficial space which reaches from Otranto at one end of the country, to Piedmont; and to the foot of the Alps generally on the other side; since the neighbourhood of Vicenza and Verona presents the same appearances. . . . . It might even be suggested that the whole of that country, even

to the highest point of the Appenines, was raised at one single period from beneath that ocean, in which we know that the limestone of this ridge was formed. Should this have been the case, the absence of the marine alluvium from the higher parts would be accounted for on the same principles which are applied to the denudations of the earth's surface all over the world."*

In the above phenomena, we have the association of an active existing cause, with effects that cannot be questioned. We feel the insecurity of the earth on which we stand; for what arose in one earthquake may be consigned by another to the bottom of the ocean. The suddenness or rapidity of the above eruptive agency, may be inferred from the undisturbed state of some of the shells and skeletons; but still more decidedly from the preservation of the animal matter in the ligaments of the bivalves, and from the condition of the fishes of Monte Bolca, as already described in Chap. ii. Book II.

The countries most easy of access, which probably contain good examples of volcanic elevation, are the Azores, and the other volcanic islands of the African coast, as well as St. Helena, Ascension, and Owhyhee. Geologists should bear in mind, moreover, "that as all the *supra marine* land has apparently been elevated by some causes, from the bottom of the sea, there may be marine alluvia beneath terrestrial ones, in many countries which show no traces of a volcanic nature, or of a volcanic origin. It must be remembered, that although the land be supposed to have been elevated from the sea, it by no means follows that this was a single event. It is much more probable that it was suc-

* Macculloch, Brande's Journal, vol. XIV. pp. 277, 278.

cessive, and that the causes operated through a long series of ages."*

The coral islands offer proofs of the elevations of submarine strata by expansive forces, acting at periods probably not very remote from our own times; and therefore they are well calculated to throw light on the more ancient and obscure phenomena of the deluge. Nearly all the islands to the south of the equator, between New Holland and the west coast of America, are the productions of *polyparies*, or, as they are commonly called, of the coral tribe of molluscous insects. But to account for the very considerable heights at which many coral islands stand out of the sea, above whose level these insects cannot build, we must have recourse to an upheaving power; and that power is obviously igneous. We have reason to believe that these organic edifices are founded on the cones of submarine volcanoes.

The coral rocks round Tongataboo are ten feet above the high water mark, a terrace which could not be formed by polyparies, or by the deposition of marine exuviæ. Interiorly, the island rises in many places 60 or 70 feet higher. In other islands, coral rocks under their most characteristic forms, have been observed, as at Eooa, at altitudes of 300 feet above the sea. Now, it will not surely be inferred that our ocean has sunk 300 feet. Nor need we resort to such an extravagant hypothesis, since the true agent of elevation reveals itself in subjacent volcanoes among these very isles. Toofooa, 70 miles from Tongataboo, exhibits a volcano always burning. Among the Friendly Isles 3 active volcanoes are known. Tafooa, we have already noticed as well as Eap to the eastward of the Carolines, both volcanic, and the latter subject to frequent earthquakes. All the coral reefs shake, when the island Ulea trembles.

* Macculloch, Brande's Journal, vol. XIV. pp. 280, 281.

In the inland and elevated parts of Owhyhee coral is observed; an island noted for magnificent volcanic operations. The soil of the adjoining island of Mowee consists of lava and other volcanic matters; along with probably the whole mountain group to which it belongs.

To the preceding instances of volcanic action among the coral islands, may be added Tanna, one of the New Hebrides, which contains a very active volcano. Messrs. Forster and Sparrman made an attempt, but unsuccessfully, to reach its burning mountain. The whole of it shook, with projection of ashes, which darkened the atmosphere; and there fell at the same time a rain composed of water, sand, and earth, which might be called a shower of slime.

Ambryn in the same group, emitted columns of white smoke, impetuously from a volcanic crater.

The Marian Islands are filled with volcanoes. La Perouse describes Assumption Island as covered in every direction with lava torrents.

To the north of the Marians, are several groups of small islands, almost all of them volcanic. Many of them indeed, have no other name than Volcano Island; and others have names of similar import, as Sulphur Island. There are two collections of coral reefs, surrounding two of these small islands, to which the imposing title Gardens has been given. Easter Island, to the east of the Society Isles, is arid and volcanic, composed of a porous, light, red lava.

From these details it appears quite certain that many of the coral isles, have like Italy been raised out of the ocean by the volcanic intrusion of matter somewhere under their base, or by a general expansive force forming vaults beneath them. It is highly probable that the numerous volcanic chimnies which like Kirauea in Owhyhee rise through the vast Pacific, are remnants of the general convulsion which raged at the deluge, ending in the submersion of some vast primeval continent, corresponding probably in area to the surface of that ocean. But this topic belongs to a subsequent chapter.

Having adverted to the coral islands, I shall introduce here such remarks about their influence in modifying the surface of the globe, as may be naturally expected to have a place in a system of geology. The rank which their insect architects hold in the zoological kingdom has been shown in the Table of living and fossil organic genera, p. 457.

The great quantity of calcareous polyparies or lithophytes, found alive in the seas of hot countries, and the considerable masses of them met with in the fossil state among our limestone rocks, have caused these animal products to be considered as forming a notable constituent portion of our continents, and as being capable of modifying in an extremely rapid and powerful manner, the submarine surface of our globe.

Such views are very common in our modern treatises on Geology. Originally founded on the observations of Captain Cook, and the other early navigators who traversed the south seas, and explored Australasia, they were corroborated in a particular manner by Forster, then by Peron, during his voyage to New Holland in the expedition of Captain Baudin, and afterwards adopted by all naturalists. It was obvious, indeed, that if the animals which produced these polyparies, designated under the general names of madrepores, or corals, by sailors and even by many geologists, grew as rapidly as those which form the *eschars*, according to Spallanzani's observations, the stony *polyparies* ought to produce, in about half a century, or even a much shorter period, by means of the beds they build up to an almost indefinite extent, calcareous masses of prodigious depth and surface. But the first position is more than doubtful, viz., that the *astreæ*, and the *caryophyllæ*, are produced with the same rapidity as the eschars; and, it is certain, besides, that these fixed animals cannot live either at great depths, where the solar light and heat exert little or no influence, or so near to the surface of the sea as to be exposed to its violent agitations, far less above that surface. Hence, in the most favourable situations, it is evident that the islands, archipelagoes, and reefs with which the Indian and South Seas are studded, cannot be altogether madreporic, as has been long believed, but merely prominences rising from the bottom analogous to those of the adjoining lands, most commonly volcanic,

which become incrusted with madreporic deposits of greater or less thickness.

This is the opinion advanced by MM. Quoy and Gaimard, naturalists of the expedition of Captain Freycinet, who after visiting the same points as Peron, and particularly Timor and the Isle of France, have undertaken to prove in a memoir on the augmentation of lithophyte polyparies considered geologically, that what had formerly been published about the immense erections which the saxigenous polypi are capable of executing, is erroneous and greatly exaggerated.

Perhaps these naturalists may have systematised a little too much in the opposite direction. They previously determined that the incrustating polyparies, as the astreæ, the caryophyllæ, and the meandrinæ, are the genera whose faculties of increase appear to be most extensive or least limited. Yet they cannot live at considerable depths, since they have never been met with below a few fathoms from the surface. By their own admission, however, the ramifying polyparies may live at a great depth, and they adduce an instance where at 80 fathoms in south latitude 56°, they obtained by sounding, small branches of living madrepores. It is known, moreover, that in the Mediterranean, even the coral tribe exists at the depth of 1000 or 1200 feet. May not *astreæ* also live far deeper than a few fathoms, though they have not been met with, since there is a great analogy between them, and certain madrepores? Or may it not be supposed that these reefs and islands, based always upon some earthy prominence of a primitive, secondary, or volcanic nature, constituting the bottom of the sea, at first shoot up to a certain height by the aid of numerous branches, of the ramifying polyparies, and are connected and consolidated by the shells which take shelter in their windings; that then the remainder may be formed by beds of astreæ, meandrinæ, and other incrustating *polyparies*, the action of which will be more lively and rapid as the animals get into more favourable circumstances of heat and light? As to the support which the opinion of Forster and Peron may derive from madrepores being observed on islands at

very great elevations, we must here carefully ascertain if the nature of these islands be not volcanic, for in this case, these madrepores might rest on the ground originally at great depths under the sea, and have been thereafter elevated with the volcanic body itself, or any other rocky mass upheaved in the eruption.

CHAP. V.—PHENOMENA OF THE DELUGE.

It has been maintained by some ingenious writers, that the whole of the antediluvian earth now lies drowned under our actual seas; and that the whole of the present dry lands, formed the bed of the antediluvian ocean. I do not mean to offer an elaborate examination of this hypothesis. Dr. Buckland, has in my opinion advanced sufficient evidence, to prove that considerable portions at least of our existing grounds, were occupied by land animals before the Noachian flood, in his ingenious theory of the hyæna caves, to be described in a subsequent chapter. These seem to have been antediluvian dens of those *carnivora*, whose exuviæ buried in diluvial loam, along with the gnawed bones of the animals on whose carcases they preyed, still attest their ancient habits and resort. That they are not postdiluvian, appears from the osteology of the animals; as the bones differ specifically from those of their existing generic types.

The texts of Scripture which have been cited in proof of the total submersion of the antediluvian world, particularly by Mr. Penn in his comparative estimate of the Mineral and Mosaical Geologies, merit the deepest reverence; but they will admit, on his own principles of criticism, of a less restricted interpretation. That the ground of the antedilu-

vians was cursed on account of Adam's transgression we are expressly assured; and we also know that its destruction was denounced in the prophetic intimation of the deluge to Noah. "I will destroy both man and beast, and the creeping thing, and the fowls of the air; and behold I will destroy them *with the earth.*" Moreover, this penal expiation of the curse due to sin, is declared by St. Peter to have been accomplished. "The world which *then was*, being overflowed with water perished; but the heavens and the earth which *are now*, reserved by the same word, are kept in store, unto fire against the day of judgment and perdition of ungodly men."

It is indeed demonstrable on physical grounds, that such a transflux of the ocean, as Cuvier's conclusion implies, must have permanently submerged a great extent of the ancient lands, and upheaved a vast tract of submarine territory. But the general tenor of the Scripture style, will certainly not warrant the theologian to insist on the arithmetical interchange of land and water, by the deluge; nor is the philosopher entitled to build his system on the above expressions of sacred writ. Expositors of the Bible allow, and indeed every attentive reader of the authorised version, cannot fail to perceive, that language apparently absolute and unlimited, is according to the idiom of oriental writers, often susceptible of a relative and modified meaning. Thus, St. Paul says, "be not moved away from the hope of the gospel, which ye have heard, and which was preached to every creature which is under heaven." Ezekiel also in comparing the Assyrian

monarchy to a cedar of Lebanon, exclaims, "All the fowls of heaven made their nests in his boughs, and under his branches did all the beasts of the field bring forth their young, and under his shadow dwelt all great nations."

But assuredly neither the apostle nor the prophet intended that the reader should understand in a strictly literal sense these passages, which merely described, in forcible words, the vast range over which the influence reached in either case. Scripture quotations to the same effect might be multiplied were it necessary; but these two will suffice to show that without some very definite limitation, many oriental phrases involve such modified meanings.

I readily concede that the territories occupied by the human race, were permanently submerged at the deluge,—probably some great continent, corresponding to the site and area of our Pacific Ocean; which still betrays in multiplied points of its expanse, the embers of volcanic violence. On this principle, Scripture truth is not violated; and thus also we can perfectly account for the non-appearance of the bones of man, and his companion animals, the sheep, the goat, the camel, &c. among the diluvial exuviæ of all the countries hitherto explored.

A *universal* deluge seems clearly proved by the utter extinction of the species of the primeval race of animals, a topic which we shall afterwards discuss at some detail. Were we not informed by Moses of the universal depravity of the progeny of Cain, as well as of the descendants of Seth whom they corrupted, a depravity to which modern crime affords parallels enow to render the history credible, we

should find some difficulty in reconciling with the counsels of a Benignant Governor so tremendous a catastrophe, implicating not only the human race, but myriads of animals, in a common destruction. But we read that Divine justice outraged, and mercy spurned, at length required their victims. "And God saw that the wickedness of man was great in the earth, and that every imagination of the thoughts of his heart was only evil continually. And it repented the Lord, that he had made man on the earth, and it grieved him at the heart."

Since geology leads us to conclude, that the earth peopled by Noah's contemporaries, perished at the deluge, complete harmony is maintained between Science, and a just interpretation of holy writ.

By a series of such subversions of the old land, and emersions of the new, within a short space of time, at an epocha of intense volcanic activity, (as exemplified in the great trap and porphyritic eruptions through the conchiferous strata,) we may explain many important phenomena of the ancient world, as well as its diluvial transition into the present, without hypothetical assumptions, or the violation of any moral or physical probability.

We shall first bestow a few thoughts on the primordial land. Consisting of primitive formations in the strictest sense of the geological word, it would prove in general a stubborn soil, prolific of every congenial weed, but ungracious to culture.* Hence, after the fertile fields of Eden were forfeited and

* Ceylon is described by Dr. Davy as one mass of primitive rock, to which the soil corresponds. Though almost universally teeming with vegetation in the interior, it is generally poor, and contains but a small

lost, the lands assigned to man might, from heat and dryness, (except in marshes overrun with ferns and equisetums,) readily favour the fulfilment of the penal denunciation, "In the sweat of thy face shalt thou eat bread;" and may make us feel the force of the prophetic hope of a better earth, expressed by Lamech at the birth of Noah his son; "This same shall comfort us concerning our work and toil of our hands, because of the ground which the Lord hath cursed." We shall afterwards see how well this prospect was realised, when the rich secondary strata were upheaved out of the waters at the diluvial *metastasis*.

A tradition of this malediction has been ever current among mankind; typified in the change from the golden to the iron age of agriculture. And probably we may likewise trace to the same origin, the singular idea of the innate malignity of matter, and of the necessary pollution of whatever is associated with it; a dogma of great importance in oriental mythology. The title *justissima tellus*, we must remember, was not applied by Virgil to lands contemporaneous with himself; but to the garden soil of his primeval paradise. The notion of the inherent malignity of matter could not be suggested by experience; that is, by any observed property of earth or clay; for it is either plastic, yielding kindly

proportion of vegetable matter, seldom more than one or two *per cent.*, proving that the luxuriant vegetation of the country, and particularly of the Kandian country, is more dependant on the high temperature of a tropical sun, *and the abundance of water in a mountainous region*, than on richness of soil, which is confirmed by the natural sterility of certain parts of the low country, that are subject to long continued droughts. *Geol. Trans. vol. V. p.* 312.

to the hand of the potter, or inert, passive, and therefore quite undeserving of reproach.

The period of the deluge is fixed by the best chronologists in the year 1656 from the creation, corresponding to the year—2348 of the Christian era. According to Blair, "On the 10th day of the second month which was on Sunday, Nov. 30th,—2347, God commanded Noah to enter into the ark with his family; and the next Sunday, Dec. 7th, it began to rain, and rained 40 days, and the deluge continued 150 days. On Wednesday, May 6th, —2348, the ark rested on Mount Ararat. The tops of the mountains became visible on Sunday, July 19th, and on Friday, Nov. 18th, Noah came forth out of the ark with all that were with him."

When the barriers of the ocean began to give way before the explosive forces, the waters would invade the shores, and spread over the sunken land,* augmenting prodigiously the evaporating surface, and thus bringing the atmosphere to the dew point, a state of saturation to which, previously, it could seldom, and in few places attain, on account of the area of the dry ground being great relative to that of the sea. From this cause, as well as from the immense quantity of vapours which are known to rise from craters into the higher and cooler regions of the air at the period of eruptions, an immense formation of cloud and deposition of rain would ensue.†

* The volcanic mountain of Pic in the Moluccas, which was visible more than 30 miles off at sea, entirely disappeared amidst a violent eruption; and a lake now occupies its place.—*Ordinaire, Histoire Naturelle des Volcans*, ch. 22.

† Ducarla, in a Memoir *on Volcanic Rains and Inundations*, published in the 61st vol. of the Journ. de Physique, speaking of the aqueous

Many persons have ascribed to the descent of rain from some super-aerial ocean, a great part, if not the whole, of the waters which then inundated the earth. But the slightest acquaintance with the principles of meteorology, would have repressed this wild imagination. The atmosphere is merely the circulating medium through which aqueous particles are transferred from moist to dry places, according to fixed laws, developed in a former chapter of this work. Supposing it universally saturated at a temperature of 80° Fahrenheit, (which is the heat of the equatorial seas,) round an aqueous sphere, it could receive vapour merely equivalent to its dew point, amounting at the utmost to a pressure of only one inch of mercury, or 13.6 inches of water. This is all that could fall from it in its transition from moisture to absolute dryness; a quantity incapable of producing a general deluge. The formation and descent of rain constitute merely a process of distillation, in which, after the dew point has been reached in any region, evaporation stops there, unless condensation takes place in another, when a direct circulation of vapour is established through the air above, and a retrograde circulation of water on the surface below. But this circulation can never raise the ordinary level of our seas in the slightest degree. In fact, such a saturation of the atmosphere would lower the general sea level by withdrawing entirely for a season, a greater mass of water into the air than usually exists in the va-

vapours then raised, says, "des qú' elles sont dans l'atmosphere, elles y forment bientôt d'énormes nuages qui se résolvent en eau, et versent des dèluges sur les contrées voisines."

porous state. We have no ground to suppose that tempestuous winds aggravated the horrors of the *rising* deluge. "The atmosphere participates very little in the agitation of volcanoes and earthquakes. It remains customarily calm. M. Von Buch when observing an eruption of Vesuvius, was surprised to see the mercury of the barometer remain perfectly steady."*

At each successive upheaving of the submarine strata, the inundation would advance further on the land, drowning in their places the animals which the dismal preludes had driven for shelter into their dens; and washing away by its reflux, the tenants of the plains, into the slimy channel of the deep. By such a retiring billow in the dreadful earthquake of 1755, 3000 inhabitants of Lisbon were suddenly swept off its quay, and swamped in the bed of the Tagus. Should a revulsion ever lay that channel dry, their bones may be found buried in the alluvium. In the progress of the elevation of submarine strata and subversion of terrestrial, the stage of equilibrium would arrive, when the circumfluent waves would roll over the loftiest pinnacles of the globe. From this consummation of the cataclysm, as the new lands continued to rise, and the old to subside, mountain peaks would begin once more to appear. During the diluvial overflow, the atmosphere would remain tranquil; for the physical causes which disturb its equilibrium—inequalities of temperature and moisture, would act feebly if at all. The universal sheet of

* D'Aubuisson Geognosie, I. 195.

water, quenched in fact for a time, the equatorial heats, which give origin to the trade winds and monsoons. And in extra-tropical regions, the usual struggle between the dry air incumbent over the plains, and the moist air over the sea, whence proceed the variable winds, was also at an end.

Nor could the shoreless abyss itself be animated by regular currents, like those which pervade our actual seas. No American barrier stretching through two hemispheres, then received the impulsion of an ocean-stream from Africa, to deflect it through a Mexican gulf, round on European shores. The disruptive forces, would doubtless agitate the mass of waters, but would also prevent their pursuing any continuous direction. Thus the animal and vegetable productions of every region would find their places of sepulture at home; for we know of no effective power that could transport them to any considerable distance.

But when the waters had so far subsided into their new basins, as to expose the mountains and table lands to the sunbeam, the atmosphere, would be set in rapid motion, and would resume its drying agency, on the new-born earth, by transferring the moisture exhaled from its intra-tropical territories, to the cold ridges of Himmala and Caucasus. Now sprung forth that great east-wind, which has ever since continued to circulate round the globe, and which as the ministering spirit of commerce, mariners love to call the trade-wind. Soon, indeed, a foreign force, would lend its impulsion to the internal causes of aerial currents. The waters in the progress of descent into their deepening channels,—

our still unfathomed ocean-caves, would take an accelerating pace, as do our ebbing tides when they approach their lowest level. With the increasing velocity of deflux, the air also would be hurried along, and thus conspiring elements would tear up and excavate the great diluvial valleys, which now furrow every district of the earth, monuments equally unambiguous and enduring of the retiring cataclysm. Of the impetus of that tremendous mass of waters, the human mind can form no adequate conception. A faint idea may perhaps be acquired from contemplating the effects of some partial floods described in modern history.

In 1225 the sea being raised to an unusual height by a storm of wind, inundated Holland. The Rhine at the same time swollen by extraordinary rains, and driven back by the tempest, spread its waters over the countries, around its embouchure. A calm suddenly supervened. The waters which had risen by rapid, but not disruptive steps, now began to run off with so furious a deflux, as to excavate and sweep away, an immense tract of ground, the bed of the Zuyder-zee.

In 1421, at another and more sudden inundation of Holland, 100,000 of its inhabitants were drowned; a hundred villages were engulphed; and in its retreat, an ocean-channel was scooped out near Dordrecht, where that great arm of the sea called the Bies-Boos stretches. We may now understand how the granites of the upper Vivarais were torn asunder into their present frightful precipices and façades; how the gigantic obelisks of the Alps and Pyrenees were insulated from their parent

mountains; and how the mighty valley of the Rhone was scooped out between its huge ramparts, the Jungfrau and Monte-Rosa, and its ruins strewed over the far distant plains of Burgundy. The enormous boulders of granite, which are spread over the Jura and neighbouring countries, have been already noticed as referred by all observers to the action of the diluvial torrents. But how much must it exalt our admiration of these sublime phenomena, to learn, from Von Buch, second to no man in mountain geology, that these rounded blocks were rolled into their present situations at the time of the rising from below of Mont Blanc and the Alpine mountains, to which they belong in composition—mountains now considered by Von Buch as the latest of all mineral formations, and newer than even the tertiary strata! Hence they are contemporaneous with the deluge, indicating at once its transcendent causes and effects.* In support of this conclusion, it should be stated, that M. Deluc of Geneva published in the Memoirs of the Physical Society of that city for May 1827, a similar opinion;—that the Alpine ridges have been formed after the tertiary rocks; and that the boulders have been dispersed by that mighty upheaving of the land. The great masses remain nearest the parent mountains, and being least travelled, are most angular; the smaller and lighter ones, having been proportionally more violently agitated, and rolled to greater distances, have got rounded by the attrition.

* Puggendorf's Annals for 1827.

The *bouleversement* involved in these propositions, and deducible from the phenomena on which they rest, must, by the established laws of physics, as we have already shown, have materially increased the area of the ocean, and diminished that of the land. To what degree this change of proportion amounted, we have no precise data to determine.

On Mr. Penn's principles the ratio of land to water was inverted by the deluge, for he assumes that our actual seas correspond in surface to the antediluvian lands; and our actual lands to the antediluvian seas. But the researches of Professor Buckland on the Kirkland and Franconia caves; as well as those of Baron Cuvier on the grotto of Oiselles, concur to prove that these were dens inhabited by antediluvian quadrupeds, and therefore must have formed a portion of its dry land. Moreover, most of our coal districts, and primitive schistose mountains, in Scotland for example, bear no good evidence of having lain under the sea during the long antediluvian period. A few shells may no doubt be found scattered over their surface, relics of the deluge, but these marine exuviæ do not constitute regular testaceous strata in their body, as would undoubtedly have happened during a long residence in the bosom of the ocean.—Our coal-measures, indeed, are most probably the basins of antediluvian lakes and marshes.

With Mr. Penn's proportion of land and water, I conceive the terraqueous globe would not have been habitable by man, and his companion animals. It would have possessed nearly three parts of earthy surface to one of aqueous, whereas there is now

fully three of aqueous surface, to one of earthy. Or since dry ground is the heating surface, and water is the cooling; the heating faculty of that ancient globe would have been three times greater than the present, and its cooling faculty three times less; making a ninefold difference in calorific constitution between the two, without taking into account the proper heat of the antediluvian seas. Under such circumstances of heat and aridity, vegetation must have pined, or most probably expired, except in a few narrow bands of soil along the margin of the sea; as is now exemplified on the Barbary shores. If we suppose that only one-half of the primeval land *perished*, at the deluge, and *that* half possibly a great continent, (corresponding to the Pacific Ocean,) which might form the whole world to the antediluvians, unversed as they evidently were in navigation, then the area of their dry land would have been equal to that of their seas.* And the general climate of their globe,

* This difference of terraqueous constitution between the old world and the new, may perhaps be made more intelligible by a simple numerical statement. Calling the total area of the globe 12, of which at present fully 9 are water and 3 land; then if three parts of land were permanently drowned at the deluge, there must have existed previously 6 parts of land, and 9—3=6 of water. The heating surface (the dry ground) would then have been double; and the cooling surface (the water) only two-thirds of its present amount. Now the general terraqueous climate, in so far as the solar influence is concerned, is as the heating surface directly, and as the cooling surface inversely; that is, as 2 to $\frac{2}{3}$; but 2 divided by $\frac{2}{3}=3$. The calorigenous quality would therefore on such a globe have had an intensity threefold, of what it has in the present state of things; which state may be represented by $\frac{1}{2}$ directly, and $\frac{3}{2}$ inversely; but $\frac{1}{2}$ divided by $\frac{3}{2}$ is obviously $\frac{1}{3}$, = the actual ratio of heat to the ancient ratio, reckoned unity. The dryness of the air would also be proportionally greater, so that the dew point, preliminary to deposition of rain drops, would be attainable rarely, and in few places.

as far as depended on the constitution of its surface, would have been three times warmer and drier than the present. This by no means implies, however, thermometric and hygrometric degrees three times higher than the present. Besides, the hotter surface of the land would be compensated by a greater radiation of heat into space, and the hotter surface of the seas by a more copious evaporation of water into the air. Still that incontestable physical principle will perfectly account, to a certain extent, for the higher temperature which prevailed in our latitudes in antediluvian times, and for the sudden and vast refrigeration induced by the deluge. I do not presume to define the numerical proportions of land and water on that ancient globe; but I maintain that such a mighty diluvian catastrophe, as it suffered, could not be accomplished by any powers of nature, which the laws of inductive logic authorise us to employ, namely general explosive and disruptive forces of volcanic origin, without increasing the area of the sea, at the expense of the land.

We must moreover keep in view the increasing obstruction of the central heat after each successive catastrophe. "Caloric penetrates solid masses so slowly," says M. Fourier, "and especially such solids as constitute the envelope of the terrestrial ball, that the intervention of a very few leagues of layers, would be sufficient to render inappreciable the impression of the most intense heat, for twenty centuries." This proposition is fully confirmed by the experiments of M. Biot on the propagation of heat in solids, even of the best conducting class. A copper bar, about 5 feet long, had one extremity plunged into melted lead, while a series of thermometer-bulbs were inserted into successive holes filled with mercury, placed along its length, at intervals of 4 inches. The following

table exhibits the differences of temperature at these equi-distant points:

Distances from focus,	6	7	8	9	10	12	14	16	18	20
Therm. dif. for 4 in.	15°	12°	10°	$8\frac{1}{4}$°	$5\frac{3}{4}$°	$4\frac{1}{7}$°	$2\frac{1}{3}$°	$1\frac{3}{4}$°	$1\frac{1}{8}$°	$\frac{3}{4}$°

Thus we see that an interval of 4 inches near the hot end made a fall of temperature equal to 15°, while the same interval near the cool end caused a fall of only $\frac{3}{4}$ of a degree. In like manner, if the increase of temperature beneath the surface of the earth be about 1° F. for every 65 feet of descent within the narrow range accessible to man, or at the cold extremity of the mineral columns, it ought to be progressively greater at more considerable depths, amounting to many degrees for the same interval of space. We may therefore safely conclude that the interposition of most imperfect conducting strata, to the thickness of 5200 feet on the bottom of the primeval ocean, would cause a diminution of initial heat in the sea-bed, of at least 80° Fahr. between the coal-measure epoch, and that of the upper courses of the tertiary strata. And finally, when the ocean was transferred from its first basin, over the mountain and table lands, so considerably removed from the influence of the central heat at their elevation from the primordial abyss, its waters would be instantaneously chilled by the transvasion. Let us call to mind that the force which brought forth the erupted rocks was expansive, and would naturally form immense subterranean vaults, interceptors of the interior heat, whose extensive communications round the globe are proved by the phenomena of earthquakes and volcanoes.

Evaporation is the grand process, whereby the excessive heats generated by the sunbeam are tempered; and we may judge of its cooling powers by the following experimental fact. By the spontaneous evaporation of one part of water, from the surface of 32 parts, at the genial warmth of 62° Fahr. the remaining 31 will be rendered ice-cold; and by the evaporation of 4 parts more, the residuary 27 will be changed into ice. On these *data*, Dr. Wollaston constructed his elegant instrument the *cryophorus*, or frost carrier. The cold produced by evaporation is very beautifully shown also in Professor Leslie's powerful mode of making ice in vacuo. If his basin of freezing water be covered, however loosely, with a disc of any kind, as glass, metal, or wood, the evaporation being suspended, the freezing immediately stops, and thawing begins.

But, geographical phenomena may perhaps be deemed by many persons still more conclusive as well as apposite illustrations of our present argument.

The cooling influence of evaporation, in regions otherwise very hot, has been remarkably evinced in Guiana, where the inhabitants, living within five degrees of the line, on the borders of immense forests, the luxuriant growth of marshy lands, were obliged a century ago, to alleviate the severity of the cold by evening fires. The drainage of the soil since then, has favoured the natural production of the heat to such a degree, that a fire in a parlour would now feel intolerable. Even the rainy season has been shortened, and thundery meteors have been diminished in consequence of the drying of the ground.

The effect of a predominant surface of water over that of land, in chilling a climate, is well shown in the greater coldness of Eastern than of Western Asia. The latter being in contact on its southern and eastern boundaries, with a wide expanse of ocean, is subject to severe cold and moisture, under latitudes which are temperate in the former. As the western region is protected by Europe on the west, from the refrigerating influence of the Atlantic evaporation, and supplied by southern winds with streams of hot and dry air from the glowing plains of Africa, it enjoys a comparatively genial climate, in zones, which towards the east become inhospitable. Had the space occupied by the Indian ocean been dry land, the northern districts of Hindostan under the tropic of Cancer, where a delightful mildness now prevails, would have rivalled in heat and sterility the burning sands of Zaara. Hence we see, that if two terraqueous globes, placed at equal distances from the sun, differed merely in the ratio of dry and aqueous surface, the mean temperature of their respective climates would be directly as the extent of their land, and inversely as that of their water.

"The trade winds," says Malte Brun, "by blowing continually from the east over the sea, contribute to render all the maritime coasts on the eastern side colder than those coasts which look to the west. On the other hand, the more a continent extends from east to west, the more those winds are heated by passing over the lands scorched by the sun. This is the reason why the Antilles or Caribbee islands enjoy so moderate a temperature, while Sene-

gambia is afflicted with the most overpowering heat of which we have any example."*

St. Helena, on the same parallel with the burning plains of continental Africa, affords, perhaps the most instructive example of the influence of a conterminous aqueous surface, in refrigerating the land. Though less than 16° from the equator, the climate of St. Helena is remarkably cool and salubrious. In James's Town the thermometer seldom rises above 80°. In the country the temperature is still more mild; being scarcely ever so hot and never so cold as in England. In some seasons, the thermometer does not rise higher in summer than to the 72d degree in the interior of the island. The average of the year is from 66° to 78° at James's Town, where the sunbeams are concentered by reflection from rocks; from 61° to 73° at the Plantation house; and from 56° to 68° at Longwood.

Likewise at Sumatra under the line, the temperature of the air is seldom higher than 85°, while in Bengal, 22° northwards, it rises considerably above 100°.

The vast extent of the antarctic seas, the total absence of any great expanse of land, and the form of the continents, which terminate towards the south, almost in points, concur to demonstrate the chilling influence of predominant water. Here for example in the island of Terra del Fuego, in that of Sandwich, and in several others situated no further from the equator than Great Britain, namely, from the 54th to the 57th degree of south latitude, the mountains *even in the southern summer, remain covered with snow, quite to the shores of the sea.*†

In fact, it is only at a distance from the seas, that the earthy surface of the globe attains its greatest heat and dryness. Mungo Park relates that in the districts of Africa which he passed through, when the wind blew from the east and north-east, the ground became so hot, that even the negroes accustomed as they were to that ardent climate, could not bear to touch it with their naked feet. While reclining in his hut of reeds, he could not hold forth his hand against the current of air, which entered the crevices, without feeling acute pain from its scorching effects. But in the southern districts of the same country, which abound in wood

* System of Geography, I. 407. † Malte Brun, I. 415.

and water, the climate becomes far more temperate, under an equally fervid sun.

In extensive inland plains, where there is no cause to disturb the equilibrium, to promote the mixture of different currents of air, and where evaporation is scanty for want of water, it seldom or never rains, as the atmosphere can hardly reach the point of saturation. On account of the diminishing moisture, the rain experienced in the Karro or Caffrarian desert is now much less than in former times. A similar change has taken place in the steppes of central Asia. In the desert plains of Africa rain very rarely falls.

"When I was at Tozer," says Dr. Shaw in his Travels, "we had a small drizzling shower that continued for the space of two hours; and so little provision was made against accidents of the kind, that several of the houses (built only with palm branches and tiles baked in the sun) fell down by imbibing the moisture."

Along the coast of Peru rain is so very rare an occurrence, that its appearance in any particular season is noticed as a remarkable event; but an ample supply of moisture is afforded by the *garuas* or dense fogs, which prevail during the greater part of the year, in that extraordinary region.

In Egypt, likewise, rain is hardly known, and in the plains of the kingdom of Yemen, a whole year passes sometimes without it.

I shall conclude the preceding enumeration of facts, demonstrative of the influence which moisture has in lowering the temperature of the earth, with some general remarks on the subject.

When water rises in vapour and forms clouds, the vast quantity of heat expended in this operation, is in a great measure lost to the earth. A notion at one time prevailed, that on the transition of invisible vapour into a vesicular or nebulous mass, the heat consumed in raising the vapour was remitted back to the air, and thence restored to the terrestrial ball. But Dr. Wells has proved that the rise of temperature, which the air and surface of the ground indicate when transparent vapour becomes

a vesicular fleece, is not perceptibly due to the latent heat of the vapour now become sensible, but simply to the dissipation from the earth, of radiant heat into space, being now intercepted by the reflecting canopy of cloud. Indeed the expansive nature of caloric, and the non-conductive faculty of air, in common with other fluids in a downward direction, preclude us from supposing that the warm strata of the upper regions, can communicate appreciable heat to the lower. Clouds in reality, act in regard to the earth in one sense, as clothing to our bodies; they obstruct the dispersion of the heat. But, in another sense, and a very manifest one, the clouds chill the earth, by intercepting and throwing back into celestial space the calorific influence of the sun. Hence the coldness which reigns often in our midsummer days, simply in consequence of a dense veil of clouds quenching or repelling the solar beam. In general, the low temperature resulting from an excess of aqueous over terrene surface, may be traced to two causes.

1. The refrigerant process of exhalation is incessant; for the vaporous atmosphere incumbent on the humid plane, in seeking the statical equilibrium, floats over the relatively drier grounds in the neighbourhood, rolls away, and thus suffers a constant series of aqueous particles to be thrown off with their charge of latent heat.

2. At certain planes of elevation in the atmosphere above the humid region, successive strata of clouds are formed, which nearly nullify the calorific power of the sun.

For these reasons, aqueous countries would be-

come much colder than we have shown them to be, were it not for aerial currents, which introduce masses of genial air from drier districts, and thus clear up the sky for a season. Causes of this kind for example, modify greatly the climate of Ireland; a country which, according to Humboldt, presents one of the most remarkable instances of the union of cold summers with mild winters. The mean temperature in Hungary for the month of August is 71.6°; while in Dublin, it is only 60.8°.

In reference to cherishing animals and plants, climate depends much more, in Humboldt's opinion, on the annual amount of solar radiation, than on mean temperature, particularly if this be merely moderate, with much moisture. It is the dry and bright sky which renders tropical regions the abodes of the plants and animals that characterise them. The lion, elephant, and rhinoceros, as well as the palms, will thrive in dry climates, though the nights be even chilly. From the travels of Ehrenberg and Hemperich in the Desert of Dongola, under the 19th degree of latitude, we learn, that in December the thermometer sunk to 38° Fahr. "Thus," says Humboldt, "we find Africa with all its rich vegetation may become colder than America, and this not on the margin of the tropics but in their very centre. We can now readily understand how on a terraqueous sphere, whose land was increased and water diminished in a moderate degree, the climate might have been so much warmer, drier, and brighter, that animals and plants at present confined to tropical zones, might flourish in far higher latitudes. With a terraqueous ratio of

equal area such as we have assigned, the equatorial zone, judging from what we know of the present globe, would be then uninhabitable, and the animals would be compelled to migrate in search of sheltering forests, refreshing fields, and waters, towards the parallels of France and Germany. And as the progress of desiccation now, is spreading the sandy deserts nearer and nearer to the Mediterranean shores, so the same cause acting with proportionably greater power on the hotter and drier primeval globe, would compel its gigantic tribes to roam towards the polar circles. Here accordingly they existed at the period of the deluge, here they perished, and found sepulture, some in the diluvial gravel, and others in the ice which immediately invested the poles when the circumfluent waters chilled the surface of the sphere.

That these circumpolar ices formerly descended on our globe into latitudes much lower than at present, involving diluvian gravel in their mass, may be inferred from the huge ruins of diluvian glaciers in Denmark, as well as from the carcasses of fossil animals found entire in Siberia.

As to the former fact, Professor Esmark has adduced satisfactory proofs of immense fields of ice having formerly existed in Norway, in places where no perennial ice is any longer to be found. Near Stavanger church in Lat. 58° 58′, there is a remarkable glacier-dyke or rampart of gravel, close to the sea, in a district where only a few heaps of perpetual snow, in hollows of the mountains, lie sloping to the north-east, at from 2000 to 3000 Rhenish feet above the level of the sea. The length of the rampart across the valley from mountain to mountain is 2250 feet, its perpendicular height above the plain 100. It consists of coarse gravel and sand, mixed with a great many huge blocks of gneiss, the prevailing rock of the mountain. The Professor thinks this dike could have

been formed only by masses of ice, which at one time filled up the whole valley, and by their pressure hollowed out the bottom into its series of 3 lakes. On the plain below, there is no trace of gravel carried down from that dike, which must have occurred if it had been accumulated by water alone. Indeed, not only the dike itself, but the whole horizontal surface exhibits proofs that there has been a glacier here, for the plain exactly resembles those adjoining to the glaciers presently existing between Londfiord and Lomb in Guldbrandsal, where the Professor had recently travelled. A skilful mineralogist who accompanied him, was so struck with the similarity between the two, that immediately on seeing that at Lomb, he exclaimed that the dike at Stavenger must also be a glacier-dike. The principal glacier in the valley of Boredhus descends from 3000 feet above the sea to 1400, with a moraine or dike of earth and stones in front, from 600 to 800 feet broad. Mr. Esmark concludes that the Norwegian mountains were anciently covered with ice down to the level of the sea, and therefore that the sea itself must have been frozen.

The facts and observations just detailed, seem adequate to prove that the events of the deluge involved such a change in the terraqueous constitution, as rendered the surface of the globe much colder and moister than it had previously been. These causes reached their maximum at that disastrous era, and have ever since been gradually but slowly abating, as I shall endeavour to show in the sequel. Meanwhile, it may be proper to notice a few prominent facts, indicative of the great and sudden fall of temperature in northern regions.

And, in the first place, the almost incredible number of bones of fossil elephants found in northern Siberia, which betray no marks of having been rolled or transported from a distance, attest the existence on its plains, of huge herbivorous animals at that distant epoch. These demonstrate that a

vigorous vegetation clothed countries now covered with frost a great part of the year, where even in summer, sterilising cold and humidity perpetually reign, and where at present the rein-deer can hardly pick up from beneath the snow its scanty mouthful of moss.

Pallas says that from the Don (the Tanais) to Tchutskoinoss, there is scarcely a river, on the banks of which, bones of the ancient elephant may not be found. They are imbedded in, or loosely covered with diluvial matter, intermixed with a few marine productions. But the most extraordinary fact, one perfectly accordant, however, with our principles, is that of all places in the world most thickly stored with elephants' bones, are certain islands of the Icy sea, to the north even of Siberia, opposite the shore, which separates the mouth of the Lena from that of the Indigirska. The Liaikof isles are in a great measure formed of bones of the elephant, rhinoceros, buffalo, &c., mixed with sand and fossil wood. There is indeed no canton of Siberia whose soil does not teem more or less with elephants' bones.

Whether these animals in their living state were covered with woolly hair at the roots of their long hair, like that whose carcass was disengaged so entire from a field of ice on the banks of the Lena in 1803, that the dogs and white bears fed upon its flesh, or whether they had naked skins, like existing elephants, still they must have required an enormous supply of vegetable food. Their gigantic companions, the rhinoceros, hippopotamus, mastodon, and tapir, also imply the existence of luxuriant herbage to satiate their voracious appetites. The fresh carcass manifestly shows that the animal perished along with its kindred, in a sudden revolution, accompanied by a sudden change of climate, which prevented the rapid decomposition of *its* flesh and *their* bones, which must have taken

place had the hot climate continued which raised their vegetable food. "Every hypothesis," says Baron Cuvier, "of a gradual cooling of the earth, or a slow variation in either the inclination or the position of the axis of the globe, is inadmissible."

At the present day, neither the oak, the hazel, the elder, the plane, nor the wild apple can endure the Siberian winters. These trees disappear in the neighbourhood of the Uralian mountains, even on the banks of the river Tobol, a prodigious distance southwards of the elephants' graves. The lime and the ash cease about the Irtysh; the pine which in Norway reaches the parallel of 70°, does not in Siberia pass the 60th degree. The silver fir goes no further than 58°. At 60° potatos are no larger than peas, and the cabbage grows no head. On the eastern side of the Lena, even the *Pinus cembra,* or Siberian cedar, the most hardy of trees, becomes quite dwarfish, though it still preserves its proportions. The *pyrus baccata* or wild pear of Daooria yields merely a tasteless fruit, of the size of a cherry. In Western Siberia on the Obi, agriculture disappears at the 60th degree of latitude. Thus three-fifths of Siberia are not susceptible of any culture.*

Secondly, the ruins of vegetable life buried in our frozen circumpolar strata, clearly attest the genial climate which prevailed, and cherished their growth on the primeval earth.

Mr. König of the British Museum who has drawn up an excellent report on the rock specimens collected by Captain Parry, during his northern voyage of discovery performed in the years 1819 and 1820, gives us the following interesting information concerning Melville Island:

"The principal formation of the island appears to be the floetz sandstone, with the subordinate one of coal and ironstone. The two specimens of sandstone, containing the above mentioned fossils, *trilo-*

* Malte Brun, Geography, vol. II. Book 37.

bite and joints of the stem of an *encrinus*, are pretty similar in appearance to those others brought from Melville Island, which abound with the vegetable remains characteristic of the coal sandstone. These are for the most part merely impressions, and filmy carbonaceous remnants of leaves (or fronds with ovate-lanceolate leaflets) and stems which, by their regularly placed oval marks, indicate that the prototypes belonged to the *arborescent ferns*, which we observe in such great abundance in the coal sandstone of more southern latitudes ; *a proof that the hyperborean region where they occur, at one time displayed the noble scene of a luxuriant and stately vegetation.* There is also among the specimens of sandstone from the same place, one bearing the impression of a thin, longitudinally striated stem, not unlike that of some reed."—*Journal of Science, vol. XV. p.* 20.

In the first fasciculus of Sternberg's Flora of a former world, there are thirteen figures of different unknown trees, many of which belong to the family of palms. All the genera enumerated in that valuable work, are met with in the coal-fields of Scotland and England, and one of them has been observed in a piece of sandstone brought from Melville Island by the discovery ships. The *Calamythis pseudo-bambusia*, represented by Sternberg, Table XIII. Fig. 3, is so completely like, in the jointed arrangement of its stem, &c. to the palmæ figured in 2, 5, and 6, of the travels of Prince Newied in Brazil, that although the species cannot be determined, there is a perfect resemblance in the generic characters.

Two of the enigmatic phenomena belonging to the primeval globe, for which no probable hypothesis has hitherto been offered, seem therefore to be directly deducible, or rather spontaneously flow, from the principles of terraqueous distribution pre-

viously developed. The first enigma is the vast extent and magnitude of volcanic agency in that ancient world, as indicated especially in its basaltic façades and domes of porphyry; compared to which every volcanic monument erected within the scope of history, shrinks into insignificance.

If the antediluvian seas had a superficial area, less than ours, their depth would be proportionally greater. Resuming, for the sake of illustration, our former ratio of an equality between the land and water (the doctrine of Deluc and Penn assigns 3 of the former to 1 of the latter), the antediluvian ocean would be to the postdiluvian in surface as 2 to 3; and in depth as 3 to 2; whence the sea would then penetrate one-half further into the crust of the earth, and thus present along its base a most formidable line of proximity with the fused and explosive metals of the interior. We may thus also perceive on what a tottering equilibrium, the devoted dwelling-place of the Cainites was suspended. During nearly the whole period of its existence, the penal fire sent forth its convulsive prodigies, as if to repress the growing wickedness of man, but in vain. Mighty memorials of these tremendous earthquakes pervade the whole masonry of the antediluvian earth, from the deep carboniferous limestone, to the uppermost tertiary beds. After many a disregarded presage, however, the disruptive consummation arrived, the deluge rushed over the subverted lands, and a more stable terraqueous equilibrium ensued. Yet, for some time, the residuary diluvial waters, would soak freely down into the still yawning crevices of the crust, and provoke fresh eruptions,

almost rivalling those of the primeval ages. To this epoch obviously belong those vast lava torrents of extinct volcanoes in France, Germany, Italy, Hungary, &c. of whose activity, there is not a traditional vestige; probably because the eruptions occurred before the posterity of Noah had colonised these western countries.

The second fossil enigma, which the superior depth of the primeval seas, enables us completely to solve, is of still greater interest than the first to the natural history of the earth. "In the organic beings buried in the shelly strata," says Humboldt, "every thing astonishes, and nothing can be explained, as to the climate which gave them birth." To the many proofs of this proposition formerly given, we shall add a few decisive documents.

The observations made during our four Arctic expeditions, viz., the one under Captain Ross, and the three under Captain Parry, afford, according to Professor Jameson, the following general facts and inferences:

"That previous to the deposition of the coal formation, as that of Melville Island, the transition and primitive hills and plains supported a rich and luxuriant vegetation, principally of cryptogamous plants, especially the ferns, the prototypes of which are now met with only in the tropical regions of the earth. The fossil corals of the secondary limestone, also, intimate that before, during, and after the deposition of the coal formation, the waters of the ocean were so constituted as to support *polyparia*, closely resembling those of the present equatorial seas."

"That previous to, and during the deposition of the tertiary strata, *these now frozen regions supported forests* of dicotyledinous plants, as is shown by the fossil dicotyledinous woods met with in connexion with these strata in Baffin's Bay, and by the fossil wood of Melville Island, Cape York, and Byam Martin Island."*

The heat applied beneath the seas, in exciting the internal motions of the aqueous particles, caused an equal distribution of warmth throughout the whole body, and in every possible direction. Though the slanting sunbeams, therefore, should have proved ineffectual to produce in the ancient arctic regions even under their diminished counteracting extent of evaporation, a sufficient warmth, yet the hot currents from the bottom, not only of the arctic grounds themselves, but from the more southern sea-beds, would by the laws of liquid equilibrium, flow towards the pole in exchange for its colder aqueous particles, and thus maintain a temperature commensurate to a vigorous vitality of the polyparies and shellfish.†

The circulation of a body of waters thus rendered tepid by subjacent heat, was the most direct method

* Edin. Phil. Journ. New Series, vol. II. p. 105; and Capt. Parry's third voyage. Captain Parry observed only 12 or 13 species of plants growing on Melville Island, among which the only one belonging to the tribe of shrubs, was *betula nana*, which was there a creeping vegetable, not rising *two inches* above the ground. No amphibia, or reptile, exists in these arctic regions. The frog alone is seen, but further to the south.

† The effect of subterranean fire in heating a vast body of water, even to the boiling point, and the steam over it under compression, much higher, is well related by Mr. Bald in his memoir on the *fires that take place in collieries.—Edin. Phil. Journ.*, *July*, 1828.

of diffusing a genial soft climate over all the contiguous lands. The efficiency of this process will be readily appreciated by the modern horticulturist, who has learned to heat his vineries, &c. with economy and precision, by circulating hot water in a series of iron pipes distributed through them.

Under such circumstances as we have now detailed, that vegetation would luxuriate, which Mr. Konig and Professor Jameson have so fully recognised amid the circumpolar ruins of the ancient earth.*

I am not conscious of having employed in the preceding investigation, any causes whose operation is not both actual and sufficient to explain the appearances. I leave others to speculate about the igneous origin of the globe, and its having spontaneously evolved during an indefinite period of refrigeration, successive orders of organic forms. This hypothesis is founded neither on natural nor revealed knowledge; nor will it accord with those great and sudden crises of temperature, which innumerable monuments attest. Baron Cuvier indeed has placed the suddenness of these ancient revolutions of the earth and animated nature, beyond all rational doubt.

CHAP. VI.—ANIMAL REMAINS OF THE DELUGE.

I HAVE already described in Chap. I. of this Book, that superficial stratum of mingled sand and gravel

* The chilling influence of damps, even in the arctic zone, is well shown by the fact, that during foggy weather, the thermometer falls on the Greenland seas *in summer* to the freezing point of water, and there remains stationary, till the sky becomes clear.

which covers almost every region of the earth, in situations beyond the reach of river deposits, and to which the name *diluvium* has been given, to denote the *detritus* of the deluge. It is in this gravelly soil that the fossil bones of ancient animals are usually found. But kindred skeletons, or their parts, have been also discovered in great numbers in the limestone caves of this and many other countries, which are supposed, with much probability, to have been the dens of antediluvian animals, the last tenants of which were drowned in the universal cataclysm. I shall dedicate this chapter to a brief but comprehensive view of these bony relics, selecting the most interesting objects, and describing in particular, the principles of that marvellous sagacity by which MM. Cuvier have taught the man of science to determine, almost at a single glance of the eye, the order, family, and species of an extinct animal, from the inspection of a single tooth. The more ancient organic remains of the regular secondary and tertiary strata were examined in treating of their sepulchres. They bear good evidence of having been inurned at a period long antecedent to the deluge.

These physical researches, elevate the mind above objects simply material; they inculcate great moral truths. In demonstrating that our earth is not peopled with the same species of animals which existed in the parent world, they display the renewing hand of Providence. The fossil elephants, rhinoceroses, bears, hyænas, &c. exhibit both in the individual bones, and their mutual adaptation, essential differences from all their living types. We

thence conclude that the divine power which raised the new earth out of the ruins of the old, must have created new animals to suit the changed terraqueous constitution. The races preserved in the ark kept seed alive for the immediate use of Noah's family.

These animals providentially transported along with them, would become domesticated during their dreary voyage, and therefore ready to tend their respective services to their masters, as soon as they were disembarked. We may easily conceive how necessary and beneficial the collective resources of brute power, and of brute instinct, might prove to eight human beings newly alighted on a strange earth. Besides the aid of their muscular exertions, they furnished in their flesh a species of food, now become necessary by the great change of terrestrial climate, from ardent and dry, to chilly and damp. Hence, animal diet was not merely permitted, but enjoined, instead of the vegetable aliments, to which mankind in the sultry period prior to the deluge, had been restricted. It would, indeed, be difficult to imagine adequate *natural* sources of subsistence, for the family of Noah, unless they had been supplied with herds of animals of many kinds, deprived of their natural timidity or fierceness, by the daily intercourse and kind offices of man.

The term *all* applied to the living things received into the ark, has, in this case, undoubtedly the modified meaning, so familiar to students of the oriental tongues, and which was formerly illustrated by two decisive parallel passages, from the Greek and Hebrew Scriptures. Had the present race of quadrupeds been lineal descendants of the antediluvian,

we may ask whence proceed those specific differences in bony structure, of which no corresponding examples occur among the skeletons of our existing species, however widely they may differ in breed, or place of residence? Thus the dog, the sheep, the horse, the ass, retain their osteology unchanged, under every climate and variety of external circumstance. The comparative anatomist can, in fact, recognise no such diversities of structure between the several individuals of any one living species, as are known to distinguish the actual elephants, from the extinct.

Had all our present animal tribes, been propagated from the ark which rested on Ararat, or some other lofty mountain in Asia, how comes it that the kanguroo, echidné, ornithorynchus, and wombat, are now confined to New Holland? Not an individual of any of these remarkable species, has been found in Europe, Asia, Africa, or America. Their absence cannot be ascribed to unsuitableness of climate, for the kanguroo and wombat have thriven well in England; and surely our immense continents offer them every variety of food and accommodation. Moses by his silence, on the great fact of the face of the earth being revived by the Creative Spirit which peopled it at first, can in nowise be said to contradict it. The critic who should construe omission into denial, would find abundant contradictions of that sort, in all sacred and profane historians.

Those who regard all our actual animals as the offspring of the primeval parents which travelled through the isthmus of the ark, will in vain seek for types of our most prolific existing races among

those diluvial ruins, where innumerable exuviæ of the elephant, the bear, the horse, the ox, the deer, are found. The ruminant class of quadrupeds are among the most abundant on our earth, yet Cuvier after all his inquiries, declares that he has never been able to find a single characteristic bone of sheep, goats, antelopes, camelopards, camels, lamas, or roebucks. "I can only say with certainty, that I have never seen a frontal bone, a nucleus of horn, an anterior piece of jaw, an occiput, in a word a characteristic bone belonging clearly to any one of these genera, which very certainly could not have happened, after the researches which I have made and others for me, during twenty years, had these genera been only one-tenth as numerous, among the fosssil ones, as those of deer or oxen. Nothing in the actual state of our globe, says he, can account for this absence. It is not the climate, for the antelope thrives in hot climates, like the elephant and rhinoceros; the mouflons, (the Corsican sheep,) the chamois, the bouquetins, inhabit cold countries, like oxen and deer. It is not the smallness, for there exist antelopes larger than deer; and the bouquetin, and the mouflon surpass the musk deer which is found among fossil animals; without adverting to that multitude of very small gnawer or carnivorous tribes which their minuteness has not concealed from our investigations. If any thing can appear singular, amid so many singularities, it is, that the fossil ruminants belong precisely to genera and even sub-genera, at present more common in the cold countries, such as the auroch,

musk-ox, elk, rein-deer, while the fossil *pachydermata* (thick-skinned order) such as the elephant, the rhinoceros, the hippopotamus, the tapir, fall on the contrary under genera, now confined to the torrid zone."*

Another remarkable fact which favours the idea of the existing animals of the torrid zone, not being derived from the species whose remains are found in our strata and caverns, is that among this multitude of great and little bones, not one belonging to the genus *quadrumanis* (ape-tribe) has been found. Among those lions, tigers, rhinoceroses, elephants, there is no trace of a monkey; nor is it the minuteness of the bones which obstructs their discovery, since fossil bones of the common rat and water-rat have been detected. How, for instance, can we explain why those Kirkdale hyænas which dragged into their dens, the dead bodies and limbs of both the greatest and smallest quadrupeds, should never have introduced an ape or a maki, unless it be supposed that no such animals existed in that neighbourhood at the time.

The theologian may probably recognise in the picture of the deluge so sublimely sketched in the 104th Psalm, allusions which favour the idea of the postdiluvian earth having been peopled with animals by a new creative fiat: while through Noah, mankind are all the children of Adam. "The waters stood above the mountains; at thy rebuke they fled; at the voice of thy thunder" (volcanic explosion?) " they hasted away. *The mountains*

* Ossemens Fossiles, IV. 2, 3.

ascend, the valleys descend * unto the place which thou hast founded for them. Thou hast set a bound that they may not pass over; that they *turn not again to cover the earth.........*Thou hidest thy face, they" (beasts both small and great) "are troubled; thou takest away their breath, they die, and return to their dust. *Thou sendest forth thy Spirit, they are created; and thou renewest the face of the earth.*"

The language of the last sentence must surely mean something more than the generation of animals, and the propagation of plants, in the ordinary way. Can it be so applied without profanation?

The difference between the diluvial skeletons, and those of their existing types must, as we have said, be deemed a strong testimony to the universality of the deluge. Had herds of these ancient quadrupeds, the fossil elephants for example, escaped, we should surely find some of their progeny alive. They were exceedingly numerous of old,—swarming in almost every country, to a degree not equalled on the present earth, as we may infer from the vast multitudes of their exuviæ which now remain, besides the far greater quantities of their bones which must have mouldered into dust. That their anatomical structure could graduate or merge into that of our actual races, no physiologist will believe to be possible; they must therefore have all perished, and been replaced by a new breed; Noah's stock probably dying out in the course of a few generations.

These monuments of antediluvian being, cannot

* These descriptive words in Italics are the Hebrew text, as printed in the margin of our Bibles.

be viewed without profound emotion. In exhuming from their earthy beds, or spar-bespangled vaults, the relics of that primeval world, we seem to evoke spirits of darkness, crime, and perdition; we feel transported along with them to the judgment-seat of the Eternal, and hear the voice of many waters coming to execute the sentence of just condemnation, on an "earth corrupt and filled with violence." The powers of prophecy overshadow us. The bony fossil starts to life, and conjures us in mysterious mutterings, to flee from the wrath to come. How solemn, to walk through this valley of death! Methinks the very stones cry out, "The Lord reigneth; righteousness and judgment are the habitation of his throne."

Such a dismal ruin of all organic beings, such a derangement of the fair frame of nature seem to be irreconcilable difficulties in *Natural* Theism. For is not the wisdom of God impeached in constructing a world on foundations so infirm; his prescience in peopling so precarious an abode, with countless myriads of exquisite mechanisms; and his goodness in plunging indiscriminately every tribe and family of his sentient offspring in mortal agony and death? A creation replete with beauty and enjoyment, suddenly transformed by its Creator's mandate or permission into a waste of waters, is a moral phenomenon which certes no system of ethics can explain. Here, metaphysics, the boasted mistress of mind, with all her train of categories, stands at fault. But here, if reason will deign to forego its pride, and implore the aid of a superior light, the Hebrew prophet will lift up the dark veil from the primeval

scene. In revealing the disobedience of Adam, the atrocious guilt of Cain, and the pestilence of sin, almost universally spread among their progeny, he shows, alas! too clearly, how justice outraged, and mercy spurned, inevitably called forth the final lustration of the deluge. This conclusion, no philosopher can reasonably gainsay, who considers man as a responsible agent, and this earth with all its apparatus of organic life, as mainly subservient to his moral and intellectual education.

Before entering on our description of these ancient animals, we shall explain the principles by which their scattered bones may be recognised and rejoined. There is in organic beings a correlation of forms appropriate to each, whereby the individual can be determined from every one of its fragments. Each animal constitutes a whole, one systematic cycle, whose parts are in mutual correspondence, and concur to the same definite action, by a reciprocal reaction. None of the parts can change, without a symmetrical change in the others; and hence, each taken by itself, indicates and gives all the rest.*

Thus, if the intestines of an animal are organised so as to digest only raw flesh, its jaws must be constructed for devouring its prey; its claws for seizing and tearing it asunder; its teeth for cutting and dividing it; the entire system of its organs of motion for pursuing and overtaking it, its organs of sense for descrying it at a distance; and even its brain must be qualified for exercising the instinct of self-concealment, and the art to ensnare its vic-

* Cuvier, Ossemens Fossiles, Discours Preliminaire, p. xlv.

tims. Such are the general conditions of the carnivorous temperament; every animal endowed with which, must combine them all, for otherwise its race could not subsist. Under the general conditions, however, there are peculiarities, relative to the size, species, abode of the prey which the animal prefers ; and from each of these peculiar conditions, result modifications of detail, in the forms emanating from the general conditions. Hence, not only the class, and order, but the genus, and even the species, are found to be expressed in the form of every part.

In fact, the jaws could not seize the prey, without a certain form of condyle ; without a certain ratio between the point of resistance of the object, point of application of the power, and the fulcrum ; without a certain bulk of temporal muscle, corresponding to a certain extent of bony cavity to receive it, and a certain convexity of zygomatic arch to let it pass through ; and this arch must have a certain strength to give a bearing to the masseter muscle.

For the animal to carry off its prey, it must possess a certain strength in the muscles which lift its head, whence results a determinate form in the vertebræ to which the muscles are attached, and in the occiput where they are inserted.

But the teeth cannot cut the flesh, without being sharp edged or pointed, and that in a greater or less degree according as they are more or less exclusively confined to the cutting of flesh. Their base must be solid in proportion to the number and size of the bones which they have to break. All

these circumstances, moreover, have an influence on the development of every part subservient to the movements of the jaws.

In order that the claws may be able to seize that prey, they must have a certain mobility in the toes, a certain strength of nails, whence will result determinate forms in all the phalanges (joints), and necessary distributions of muscles and tendons. The foreleg must have a certain facility of turning about, which implies appropriate forms in its component bones; and as the bones of the foreleg are articulated with the *humerus*, they cannot be changed, without inducing changes in it. The shoulder bone must have a certain degree of firmness in the animals that employ their forelegs in seizing bodies, whence peculiar forms arise. The play of these several parts will require certain proportions in the whole of their muscles: and the impressions of muscles thus proportioned will determine also more especially the forms of the bones.

We can easily see that similar conclusions may be formed as to the posterior extremities, which contribute to the rapidity of the general motions; as to the composition of the trunk, and the forms of the vertebræ, which involve the facility, and flexibility of these motions; and as to the forms of the bones of the nose, of the orbit, of the ear, on account of their obvious relations to the perfection of the senses of smelling, seeing, and hearing.

In short, the form of the tooth entails the form of the condyle; and that of the shoulder blade, the form of the nails, just as the equation of a curve includes all its properties; and, as by assuming

each property separately as the base of a particular equation, we should reproduce, both the ordinary equation, and all its properties whatsoever, so the nail, the shoulder blade, the condyle, the thigh bone, and all the other bones taken separately, give the tooth, or are given by it in their turn. In starting, therefore, from any one of them, the naturalist who possesses a thorough knowledge of the laws of the organic economy, could reconstruct the entire animal.

This principle in its general acceptation, is sufficiently evident, without any further demonstration; but in attempting to apply it, a great many cases occur where our theoretic knowledge of the relations of the forms, would be insufficient, without the aid of observation.

We perceive, for example, that hoofed animals must be all herbivorous, since they have no means of laying hold of prey; we see also, that having no other use of their fore-feet than to support the weight of their bodies, they have no need of a shoulder so powerfully constructed. Hence their want of the clavicle and acromion, and the narrowness of their shoulder blade. Having besides no occasion to twist their foreleg, their *radius* will be soldered to their *ulna*, or at least articulated by the hinge, and not the socket joint with the humerus; their herbivorous diet will require flat crowned teeth for bruising seeds and plants; the crown must also be unequal, from the alternation of the enamel and osseous portions; this kind of crown demanding horizontal movements in trituration, the

condyle of the jaw bone, will not be so confined a hinge as in carnivorous animals, but must be flattened, corresponding to a more or less flattened *facette* of the temporal bone; and the temporal fosse, having to receive but a small muscle, will be narrow and of little depth. All these things flow from one another, according as they are more or less general; some being essential and exclusively appropriated to animals with hoofs; and others though equally necessary to them, but not peculiar, being found likewise in some other animals, where the rest of the conditions permit. Had not observation informed us, we should not probably have divined, that all ruminating animals have a cloven foot, and they alone. It is moreover doubtful, if we should have inferred *a priori*, that none but animals of this class would have horns on their forehead; and that those of them which had sharp canine teeth, would be the only ones without horns. Yet since these relations are uniform, they must have a sufficient cause; but as we do not know it, observation must supply the deficiencies of theory. We thereby establish empirical laws which become almost as certain as rational ones, when they repose on observations often enough repeated. Whoever at the present day sees the print of a cloven foot, may safely conclude that the animal which left that impression, chews the cud; a conclusion as certain indeed as any in physical or moral science.

This single foot-print, then, affords to the observer, at once the form of the teeth, the form of the jaws, the form of the vertebræ, and the form of

all the bones of the legs, the thighs, the shoulders, and the pelvis of an animal which has merely walked past without being seen.

That there are secret reasons, however, of all these relations, observation alone can suggest, independently of general philosophy. In forming a tabular view of these relations, we recognise not only a constancy of specific characters, so to speak, between such a form of such an organ, and such another form of a different organ; but we perceive at the same time a constancy in the classic characters, and a correspondent gradation in the development of these two organs, which display almost to demonstration, their mutual influence.

For example, the dental system, of non-ruminant hoofed animals, is in general more complete than that of ruminant animals with cloven feet; because the former have either incisor or canine teeth in both jaws. The structure of their foot is in general more complex, because they have more toes, or have nails (hoofs) which leave the phalanges more free, or a greater number of distinct bones in the metacarpus and metatarsus, or more numerous tarsal bones, or a *fibula*, more distinct from the *tibia*, or lastly because all these circumstances are often combined. It is impossible to give reasons for these relations; but they are clearly not the result of chance, because whenever a cloven-footed creature shows, in the arrangement of its teeth, some tendency to approach to the animals under consideration, it exhibits a similar tendency in the conformation of its feet. Thus the camels possessing canine teeth, and even two or four incisors in the upper

jaw, have an additional bone in the tarsus, because their *scaphoid* bone is not firmly adherent to the cuboid; and they have very small hoofs, with corresponding ungual phalanges. The musk animals, in which the canine teeth are strongly developed, have a distinct fibula along the whole length of their tibia, while the other cloven-footed kind, have, instead of a fibula, merely a small bone articulated to the lower end of the tibia. Hence a constant harmony subsists between two organs apparently quite alien to each other; and the gradations of their forms have an uninterrupted correspondence, even in cases where we can see no reason for their relations.

By adopting, in this manner, observation as a supplementary means when theory fails, we arrive at results calculated to astonish. The least *facette* of a bone, the smallest apophysis (bony process) has a determinate character, relative to the class, order, genus, and species, to which it belongs, so that whenever we get merely an extremity of a bone in good preservation, we can, by diligent application, and by availing ourselves with a little address of analogy, and careful comparison, determine all those things as certainly, as if we had the whole animal under our hands. M. Cuvier has often verified this method on portions of well known animals, before bestowing confidence on it, with regard to fossil species; and it has afforded him such infallible success, as to leave no doubt of the certainty of its results.

He enjoyed indeed every desirable co-operation. His fortunate appointment as superintendent of the

Museum of Natural History, joined to an assiduous research for more than 25 years, furnished him with skeletons of all the *genera* and *sub-genera* of quadrupeds, with many species of certain genera, and several individuals of some species. With such resources, it became easy for him to multiply his comparisons, and to verify in all their details the applications which he made of his laws.

In this way, he has determined and classed the remains of nearly 100 quadrupeds, mammiferous or oviparous. Considered in reference to species, upwards of 70 of these animals were previously quite unknown to naturalists; 10 or 12 have so perfectly resembled known species, that no doubt can remain of their identity; the others present many kindred features with known species, but the comparison has not hitherto been made in a sufficiently scrupulous manner to remove all ambiguity. Viewed in reference to the genera, out of these 70 unknown species there are nearly 40 animals which belong to *genera* that are new. The other species are referrible to *genera* or *sub-genera*.

It may be useful also to consider these animals with respect to the classes and orders to which they belong.

Of the hundred species, about one-fourth part are oviparous quadrupeds, and the rest are mammiferous. Among the latter, more than one-half belong to non-ruminant hoofed animals. It would, however, be premature to establish onthese numbers, any conclusions relative to the theory of the earth, because they are not in a necessary ratio with the numbers of the genera or species which may be

buried in our strata. Thus there have been collected many bones of the large species, which are most obvious to the quarriers, while those of small species are usually neglected, unless accident should make them fall into the hands of a naturalist, as was the case at the Kirkland cave, with Professor Buckland; or unless some peculiarity, as their extreme abundance in certain places, should attract the attention of the vulgar.

That the extinct species are not varieties of the living species, M. Cuvier has proved by an ample induction of facts. *A species comprises all the individuals which descend from one another, or from common parents, and those which resemble them as much as they resemble each other.* Hence the *varieties* of a species are merely breeds more or less different, which may issue from them by generation. Our observations on the differences between ancestors and descendants, constitute therefore our only rational rule; for every other would fall under the head of hypotheses devoid of proofs. Although the wolf and the fox inhabit every country from the torrid to the icy zone, they experience in this immense interval, hardly any other change, than a little variation in the beauty of their fur. M. Cuvier compared the skulls of foxes from the north of Europe, and from Egypt, with those of France, and he found no individual differences.

The varieties of the wild animals which are restricted to more limited spaces, differ still less, especially the carnivorous. A more bushy mane forms all the difference between the hyæna of Persia and Morocco.

The wild herbivorous animals experience somewhat more deeply the influence of climate, because that of food co-operates, as to its abundance and quality. Thus elephants will grow larger in one forest than in another; and they will have tusks a little longer in situations where the food is favourable to the formation of the substance of ivory. The same circumstance will hold with rein-deers and stags in reference to their antlers; but let us take the two most dissimilar elephants, and we shall not be able to observe the least difference in the number or articulations of the bones, or in the teeth, &c.

The herbivorous species moreover in the wild state, appear to be confined within a narrower range than the carnivorous, because the nature of their nourishment combines with temperature to limit their dispersion.

Nature has provided against the alteration of species, which might result from their mixture, by the mutual antipathy which it has given them. It requires every artifice, and all the power of man, to make these unions be contracted, even among species in closest affinity; and when the offspring are not barren, which they commonly are, their fecundity does not extend beyond a few generations, and would probably not continue at all without a renewal of the cares which excited it. Hence we never perceive in our woods, individuals intermediate between the rabbit and the hare, between the stag and the doe, or between the martin and the weasel. The tyranny of man alone can alter this order; it develops all the variations compatible with the type of each species, and obtains productions which the

species would never have brought forth when left to themselves. Here the degree of the variations is still proportional to the intensity of their cause,—slavish coercion. The changes do not amount to much in the half-domestic species, as the cat. Softer hair, more lively colours, a larger size, are all the variations; for the skeleton of an Angora cat, differs in no constant particular from that of a wild one. Among herbivorous animals, which are transported into the most opposite climates, subjected to every sort of diet, and to which different kinds of labour and food are dealt out, we obtain greater variations; but they are still superficial. A greater or less size; longer or shorter horns, which are also sometimes wanting; a thicker or thinner wen of fat on the shoulders, form the differences among oxen, and these differences are preserved for a long time, even in breeds exported from their native countries, though pains be taken to remove them. Of this kind, are also the innumerable varieties of sheep, observable chiefly in the fleece, because it is the main object of commercial interest. Among horses, the differences are a little less, but still quite perceptible.

In general the shape of the bones varies little; their connexions, their articulations, and the form of the great molar teeth, never change. The slight development of the tusks, in the domestic hog, and the adhesion of its hoofs in some individuals of the breed, are the utmost extent of the differences which man has been able to produce in domestic herbivorous animals.

Amid all possible variations, in the external aspect

and configuration of dogs, the relations of the bones remain the same, nor does the form of the teeth ever vary in an appreciable manner. At the utmost, some individuals push forth an additional false grinder, sometimes on the one side, and sometimes on the other; and as in the human species, there are some six-fingered families, so there is a breed of dogs, with one additional toe, and a correspondent tarsal bone, on the hind foot.

There are therefore in animals, characters which resist every influence, whether of nature or man; nor does any thing indicate that time can exert with regard to them, a greater effect than climate and domesticity. "Some naturalists," says M. Cuvier, "reckon much on the thousands of ages which they accumulate with a dash of their pen; but in such matters we cannot venture to judge of what a long time might operate, except by multiplying in idea what a shorter period does produce. I have therefore collected with care the most ancient documents concerning the forms of animals, of which none now in being, equal in antiquity and abundance, those furnished by Egypt. This country presents us not only with pictures of animals; but their very bodies embalmed in its catacombs.

"I have examined with the greatest pains, the figures of animals and birds, engraved on the numerous obelisks brought from Egypt to ancient Rome. All these figures have, when viewed as wholes, (which was the only object of their artists,) a perfect resemblance to the species, as we see them now-a-days."

M. Geoffroy Saint-Hilaire collected in the tombs

and temples of Upper and Lower Egypt, as many animal mummies as he could. He brought home with him, cats, ibises, birds of prey, dogs, apes, crocodiles, and a head of a bull, all embalmed; and certainly no greater difference can be perceived between these beings, and those which are now most familiar to us, than between human mummies, and the skeletons of the modern race of men. M. Cuvier has proved in a special memoir on the ibis, that this bird is now the very same animal in every respect, as it was in the days of the Pharaohs.

"No ascertained fact, therefore, countenances in the slightest degree, the opinion that the new *genera* discovered or established among the fossil skeletons, such as the *palæotheriums*, *anoplotheriums*, *megalonyx*, *mastodontes*, *pterodactyles*, *ichthyosauri*, *plesiosauri*, *megalosauri*, *iguanodontes*, &c. have been the parent stocks of any of the animals of the present day, which animals owe their differences to the influence of time or climate. Were it true (which I am very far from thinking), that the fossil elephants, the rhinoceroses, the elks, the bears, differ no more from the existing ones, than the breeds of dogs differ from each other, we are not on this account warranted to conclude that the species were identical, because the canine race has been subjected to the influence of domesticity; while these other animals have neither suffered nor could endure it.*

The first order of fossil quadrupeds examined by Cuvier, is the *pachydermata*, (thick skinned.) It

* Baron Cuvier, Ossemens Fossiles, Discours Prelim. p. lxiii.

comprehends non-ruminant, hoofed animals, under the following 13 genera; the elephant, mastodon, rhinoceros, hippopotamus, tapir, hog, horse, daman, pecaris, phacochères, anoplotherium, palæotherium, elasmotherium.

I. Elephant.

The vast marshy and sandy plains of Siberia, wherever they are scooped out by rivers, discover osseous remains. The Irtisch between 55° and 56° N. Lat. has very high banks, on which the waters lay bare from time to time, ivory tusks and other bones of elephants. To the north of Berezof, N. Latitude 65°, high hills skirt the Oby, forming precipitous banks, composed of plastic clay and sand. They display abundance of elephants' bones, mined out by the currents. The lower parts of an island in the Frozen Sea under 72° N. Lat. consist of ice and sand; and whenever a thaw causes a portion of its coast to crumble down, plenty of fossil bones appear. In Siberia they are often associated with some marine exuviæ, as sea shells and sharks' teeth, buried under several distinct strata of clay and sand, showing that an alluvial process had continued for a considerable period to cover the bones. Similar mixtures of these bones and shells in alluvial strata, are found at the Jaik, Kama, Toura, and Oby. Lieutenant Kotzebue discovered in his late voyage, teeth and bones of elephants entangled in an iceberg, on the north-western angle of the American continent, close to Bering's Strait. What a rich vegetation must have anciently flourished in these now desolate regions, to have nourished so many thousands of these enormous animals! The fossil tusks indeed, constitute a very lucrative article of commerce to the natives. The Siberians call the animal *mammoth* (animal of the earth), from a notion that it was a subterranean quadruped, of similar instincts with the mole.

Bones of the fossil elephant were so abundant on the loamy hills, which border the valley of the Arno near Florence, that the peasants formerly used them along with stones for building the rude partition walls of their fields; and two entire apartments belonging to the Valdarnaise Academy at Figline, are filled with elephants' bones which were exhumed in the immediate neighbourhood. Many bones of the rhinoceros and hippopotamus also are

here promiscuously mingled. To the north of the Appennines likewise the same fossil remains are abundantly found; and indeed scarcely any district of Italy seems to be without them. They occur in many parts of France, the Netherlands, Holland, Germany, particularly at Caustadt and Tonna on the Necker, where a whole forest of the trunks of palm trees lies buried. A remarkable congeries of fossil elephants' bones was discovered at Thiede near Wolfenbuttle, mixed with bones of rhinoceros, horse, ox, and stag. There were 11 elephant tusks, one of them 14 feet 8 inches long, bent into a perfect semicircle; and about 30 grinders. An entire skull was dug out of the soil, at Osterode at the foot of the Hartz mountains opposite Göttingen, along with bones of the rhinoceros. On the banks of the Elbe also, and in Bohemia, many such bones are found, nay even in Scandinavia and in Iceland.

In England, the teeth, tusks, and bones of elephants of prodigious size have been found in diluvium in Robin Hood's bay, near Whitby; at Scarborough; Bridlington, and several other places along the shore of Holderness; as also in the interior of Norfolk, Suffolk, and Essex. Near Harwich, at Walton, in a mass of diluvial clay, between high and low water mark, there was a large deposit of them, mixed with bones of the hippopotamus, horse, &c. On the banks of the Thames they are extremely common; as at Sheppey, the isle of Dogs, Lewisham, London, Brentford, Kew, Hurley Bottom, Wallingford, Dorchester, Abingdon, and Oxford. At Norwich, Canterbury, Chartham near Rochester, Lyme Regis, Charmouth, Abbotsbury, Burton, Loders, near Bridport, near Yeovil in Somerset, at Whitchurch near Dorchester, on Salisbury plain, in the valley of the Avon, in that of the Severn, at Trentham in Staffordshire, and abundantly at Newnham and Lawford near Rugby in Warwickshire. Elephants' teeth and bones are often found in digging foundations and sewers in London, as under 12 feet of gravel in Gray's-Inn Lane, and at a depth of 30 feet on the east of Waterloo-place. At Kingsland near Hoxton, an entire elephant's skull was discovered in 1806, containing 2 tusks of enormous length, as well as the grinders. All the gravel pits round about London seem to afford them. In the gravel pits of Oxford and Abingdon, teeth and tusks and various bones of the elephant, are found mixed with the bones of rhinoceros, horse, ox, hog, and several species of deer; often crowded together in the

same pit, and seldom rolled or rubbed at the edges, although the several bones are not assembled so as to complete a skeleton.*

Wales, Scotland and Ireland have also afforded elephants' tusks or bones.

Blumenbach states in his *Archæologia Telluris*, published in 1803, that more than two hundred elephants and 30 rhinoceroses, had been found in Germany. Many have been discovered since, as the congregated heaps at Seilberg near Canstadt, and at the village of Thiede, contiguous to the town of Brunswick.

Bones of the fossil elephant occur in considerable abundance in North America, where no living elephants have ever been known to exist; and Humboldt found them in the plains of Mexico, and in the province of Quito.

All the above localities belong to the diluvial gravel or loam; but there are many elephants' bones likewise in limestone caves. In England, bones of the fossil elephant have been found in the caverns at Kirkdale, Wirksworth, Mendip, Crawley rocks near Swansea, and Paviland caves near Swansea. And on the continent, in caves in the district of Muggendorf, and at Fouvent in France. A most interesting description of these caverns, with very instructive plates, will be found in Dr. Buckland's work, quoted below.

Comparison of the fossil elephant with the living.

There are three distinct species of this genus.

1. The African, which inhabits the Cape, Senegal, and Guinea.

* This enumeration of the English localities is from Professor Buckland's excellent Reliquiæ Diluvianæ, 2d Edition.

It has a rounded skull, large ears, grinding-teeth marked with lozenges in their crown (upper face).

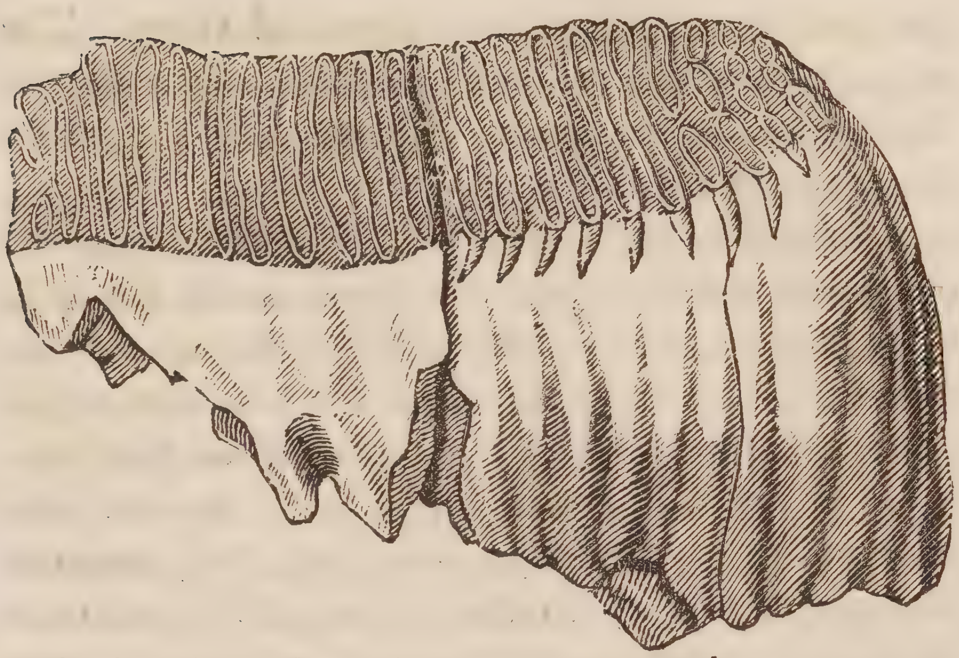
2. The Indian, found on both sides of the Ganges, and in the islands of the Indian seas, as Ceylon, Java, Borneo, Sumatra, &c.

It has an oblong skull, concave front, small ears, and grinders marked with waving ribands.

3. The fossil or primeval elephant (elephas primigenius), mammoth of the Russians. It has an oblong skull, concave front, very long bone-sockets of its tusks, lower jaw obtuse, broad parallel grinders, marked with narrowish ribands on the crown.

Its bones are found only in the fossil state; no similar recent ones have ever been seen. The fossil elephant resembles more the Indian than the African species; but differs from the first, in the form, of its grinders, of its under jaw, and several other bones; especially in the length of its tusk-sockets or alveoli. This latter character must have modified singularly the figure and organisation of its proboscis, and given it a physiognomy much more different from that of the Indian species, than might be inferred from the resemblances of the other bones. Its size *(taille)* was about that of the Indian, from 8 to 15 or 16 feet; but perhaps it was a little thicker and more squat.

The wood engraving at the top of the following page, is an elephant's tooth, copied exactly from Plate VI. Fig. 1, of the first volume of the *Ossemens Fossiles*. It seems to have been cracked across by some violence; but it is very characteristic.



The above figure of a fossil tooth represents of $\frac{1}{5}$ the natural size, an under-grinder of an old elephant, found some years ago, along with its fellow, buried 18 feet deep in black earth in the Forest of Bondy, near Paris. It has 24 ribands, or plates of enamel crossing the surface. These fillets are usually narrower in the fossil, than in the living species. Hence the former could have more grinding plates in action at once than the latter can; which are seldom more than 10. The fossil teeth are usually broader than the living in the proportion of about $3\frac{1}{2}$ to $2\frac{3}{4}$ inches; and their ribands are less festooned.

From its skeleton, M. Cuvier concludes that it differed more from the Indian elephant, than the ass does from the horse, or the jackall and isatis from the wolf and the fox.

The bones must have been interred by some general physical cause; for they are too numerous, and dispersed over too many deserts, and uninhabitable countries, to admit of the supposition of the animals having been conducted thither by men.

Most part of the bones are not at all water-worn, but have their edges, and their processes entire; showing that they have suffered no kind of friction. The *epiphyses* of bones which had not acquired their complete growth, still adhere, though the

slightest force would have detached them. The only changes which they have suffered, are due to decomposition produced during their long residence in the earth.

Every thing therefore concurs to show that the elephants which owned the fossil bones, dwelt in the countries, where their remains are now found; and that they disappeared in a revolution which destroyed all the individuals existing at the time. Whatever was the cause, says Cuvier, it must have been sudden. The large bones and ivory tusks so perfectly preserved in the plains of Siberia, must owe their soundness to the cold which suddenly froze them up, or which counteracted the natural decomposing influence of the elements. Had this cold come on by degrees and very slowly, these bones, and *a fortiori*, the soft parts with which they are still sometimes clothed, would have had time to decompose, as happens to the elephants which now die in hot or temperate countries. Certainly it would have been quite impossible for a whole carcass, such as the one discovered by Mr. Adams, to have preserved its flesh and skin, without corruption, had it not been immediately embalmed in antiseptic ice.

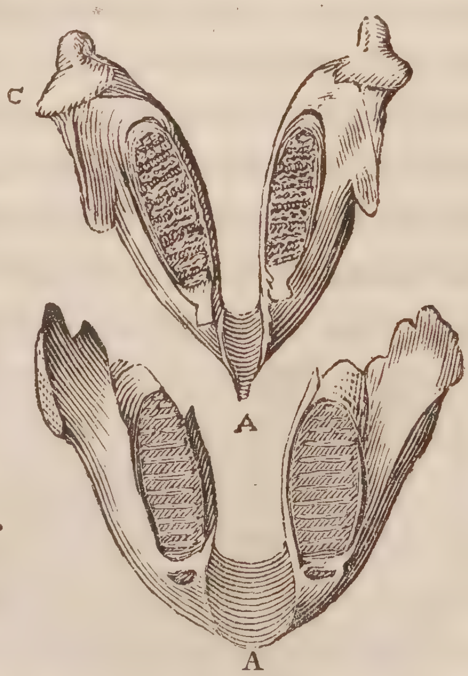
"Thus every hypothesis of a gradual refrigeration of the earth, or a slow variation, either in the inclination, or in the position of the axis of the globe, falls to pieces of itself."*

Were the actual elephants of India, the descendants of those ancient fossil elephants, which had taken refuge in their present climates from the

* Cuvier, Ossemens Fossiles, I. 203.

catastrophe which destroyed their race elsewhere, we may ask, why their species was destroyed in America, though bony relics still attest their ancient existence, in the vast empire of Mexico,—a country which afforded sufficient elevations for escaping from an inundation so moderate as is implied by that hypothesis? That region was besides as hot as their habits required.

The different *mastodontes*, fossil *hippopotamuses*, and *rhinoceroses*, must have lived in the same countries, and cantons, as the *fossil elephants*, since we find their bones in the same diluvial beds, and in the same state. No cause can be conceived which could destroy the one and spare the others. Yet the mastodons most assuredly exist no more; in respect to them there is no doubt or disputation.

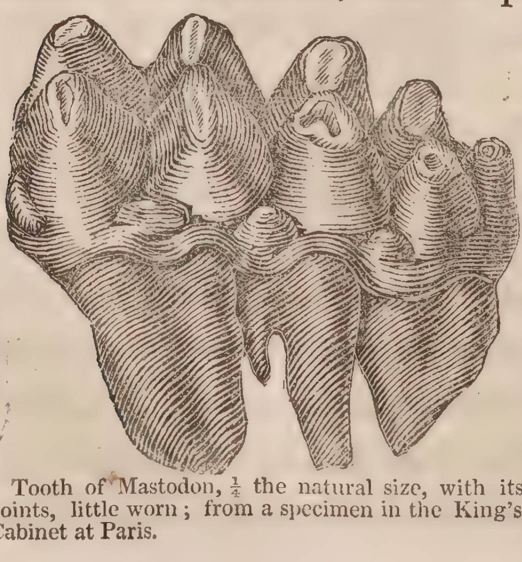


The uppermost figure represents the under jaw of the living elephant; the lowest figure that of the fossil. The sides of the former converge to a point, and have a projecting peak at A in front, furrowed with a long narrow canal. The teeth in the jaw of the fossil elephant stand parallel to each other on its opposite sides; and the canal in front is much shorter and wider. In the two living species, the African and Indian, the tusk-sockets (*alveoli*) do not extend further down than the level of the lower jaw;

so that the chin has room to protrude between the tusks in a pointed projection. But in the fossil heads, on the contrary, on account of the great length of the tusk-sockets, the lower jaw has been truncated or blunted off before, to admit of the lower jaw closing on the upper one in the act of mastication.

Every thing, therefore, concurs to make us conclude that the *fossil elephant* certainly belongs to an extinct species, although it resembles one of the existing species more than the mastodons do. Its extinction likewise has been produced by a sudden cause, by that same great catastrophe which destroyed all the species of the same epoch; of which abundant evidences remain among the other animal exuviæ.

II. *Mastodon.* Of this extinct genus we have, according to M. Cuvier, six species buried in the *diluvial* detritus. 1. The great mastodon; 2. The Mastodon with narrow teeth; 3. The Mastodon of the Cordilleras; 4. The Mastodon of Humboldt; 5. The small Mastodon; 6. The tapiroid Mastodon. To these 6, we must add two other species, the Mastodon latidens, and elephantoides of Mr. Clift.



Tooth of Mastodon, $\frac{1}{4}$ the natural size, with its points, little worn; from a specimen in the King's Cabinet at Paris.

The genus *Mastodonte* is so named because its *molares* or grinding-teeth instead of being formed of transverse plates, like those of the elephant, have a simple crown, studded with tubercles or nipples more or less

numerous, and prominent. These ancient animals had the size and figure of the elephant, were provided like it with a proboscis, and long tusks planted in the incisor bones of the upper jaw, with feet of the same structure, and distinguishable mainly by their teeth. Our actual continents now breed no animal of this genus.

It was originally inferred from the mammelated form of the teeth that the animal had been carnivorous, a mistake fully refuted by the illustrious naturalist of France. The first notice of the mastodon is in a letter from Doctor Mather in America to Dr. Woodward in London, dated 1712, intimating that bones and teeth of monstrous magnitude had been discovered in 1705, in Albany in New England, at present in the state of New York, near Hudson river. He imagined them to be the bones of giants. No interest was excited, however, till Mr. Croghan, an English geographer, in 1767, sent several chests of these osseous remains to Lord Shelburne and other persons in London. Dr. W. Hunter published an accurate description of a lower jaw in the Philosophical Transactions for 1768. He demonstrated that the animal in question while it differed distinctly from the elephant, had nothing in common with the hippopotamus, and he justly ascribed to it the tusks found along with the bones.

In the year 1802, Mr. Peale of Philadelphia having procured numerous bones of the same animal from a brackish marsh in the neighbourhood of Newburgh, on the Hudson river in the state of New York, formed two skeletons out of them, copying artificially in wood from the bones of one of

them, and of one side of either, what was needed to make up the deficiency of the others. Henceforward the osteology of this large animal became perfectly known, if we except merely the upper part of the cranium.

M. Cuvier concludes, after his usual diligence of research, that no bones of the great mastodon have been hitherto found in Europe. They occur most abundantly in the brackish marshes on the Ohio, which are called there big-bone-licks, from the circumstances of their saltness and their osseous contents. In the state of Kentucky, about 4 miles south-east from the left bank of the Ohio, and 36 miles above the entrance of the river Kentucky, there is an extensive marsh, surrounded with hills, which is fed with a streamlet of salt water, from whose black and fetid mud, a few feet below the surface, an enormous multitude of these bones have been extracted. Croghan thought that he saw here the remains of about 30 individuals; but a far greater number have been dug out since. These bones are accompanied with those of other animals. On the two sides of the streamlet the earthy beds are composed almost entirely of bones of buffaloes, stags, and other smaller animals.

Bones of the mastodon are also found in all the temperate regions of North America, in whatever direction it may be explored. The late Smith Barton gives, in his Journal of Natural Philosophy and Medicine for Philadelphia, a detailed account of five nearly entire skeletons having been found in 1762 by the Shawanais savages higher up on the Ohio, about 3 miles from its margin in a brackish flat, of which a grinder and a piece of a tusk had been brought to Fort Pitt. The furthest south point, at which the mastodon bones have been found, is in the country of the Apelouses

in Louisiana, among the muds of the Mississippi, in 31° N. Lat. They have not hitherto been observed further north than in 43° N. Lat. on the side of Lake Erie. M. Cuvier finds that the teeth brought home from Peru by MM. Dombey and Humboldt, do not belong to the great mastodon, but to another species. He supposes those from Lima and Brazil, spoken of by Dr. W. Hunter, to be in the same predicament.

The ferruginous matter with which the bones of the great mastodon are impregnated, is the best proof of their long residence in the earth. No marine remains have been seen associated with them.

Description of the great Mastodonte.

The molar teeth are very characteristic. Their crown in general approaches more or less to a rectangular figure. It contains only two substances; the interior called osseous or more properly ivory, and the exterior or enamel. The latter is very thick. There is none of that third substance, so remarkable in the elephant, called the cement or cortical matter, which envelops the rest of the tooth, resembling ordinary bone in chemical composition and hardness. Sir E. Home terms this substance bone, and the other inner substance, ivory.* The crown of the mastodon's molaris is

* The *cortical* is secreted in life by the same organic membrane, and the same face that produces the enamel. This membrane remains outside of the cortical, as it was at first outside of the enamel, continuing soft and loose as long as the cortical leaves room for it. It only changes in texture; having been thin and transparent whilst it secreted enamel. When it begins to furnish cortical substance, it becomes thick, spongy, opaque, and ruddy. This cortical matter does not grow by closely aggregated meshes, but as it were by little drops seemingly secreted at random. The deposition of the enamel commences almost with the transudation of the osseous substance, and that of the cortical follows soon thereafter, so that the summit of each plate is finished in its three substances long before its base; and the contiguous laminæ are cemented together at the top before being indurated at their bottom.

The substance of teeth is formed by secretion in layers; the inner

divided (see figure, p. 526), by furrows or a species of spreading valleys, into a certain number of transverse hills, and each hill is itself divided by a groove into two thick points, obtuse, forming irregular quadrangular pyramids, slightly rounded at their edges. Till this crown be worn down by mastication, it is studded with thick points standing in pairs. There is a wide difference between these and the teeth of *carnivora*, which have only a main longitudinal edge, divided by vertical slits, like the teeth of a saw.

The mastodon must have made the same use of its teeth as the hog and the hippopotamus, which possess the same dental characters. It would search after succulent vegetables, roots, and aquatic plants; but it hunted not for nourishment, in living prey. This trituration of vegetable diet wore down the nipples of its teeth, bringing the crown into the blunted flat state which so frequently occurs; in some cases the pyramids being only partially rubbed away, and in others being smoothed down, into a surface of osseous substance surrounded with enamel. The section of each of the pyramids, somewhat under its apex, represents a lozenge. The roots of these teeth, like those of all others, are not

substance in particular has nothing in common with ordinary bones, except as to its chemical composition, of gelatine and calcareous phosphate, but it possesses no resemblance, in texture, mode of deposition, or of growth. Its tissue is neither cellular, nor fibrous, but consists of plates laid together. Those who compare it to the diplöe of the skull, supposing it full of cells, give false ideas of its nature. Hence no part of a tooth is regenerated when it is worn away. Anatomists have been therefore much to blame in designating by the term ossification, the vital function which develops and indurates teeth.—*Cuvier, Ossemens Fossiles, Tom. I. p. 35, et seq.*

formed till after the crown, and are never found complete till the teeth show a little wearing. From the thickness of the enamel, the collar or neck of the tooth is much swollen.

The disposition of the grinders in the adult mastodon, is four in each jaw; of which the two front ones in the upper have 6 points, and the other two have 8; in the lower, the two anterior have 6 points, and the two posterior 10. It moreover appears, that the great mastodon had, *successively*, at least four grinders in every side of its jaws; but, as happened to the elephant, these teeth never appeared all together in the mouth. *Their succession* took place, in both animals, from behind forwards. When the posterior one began to cut the gum, the anterior one was greatly worn and ready to drop out. In this way, they replaced one another. There does not seem to have been ever more than two on each side in full exercise; and finally, only one as in the old elephant. Thus the *effective number* of molar teeth which could act together was 8 in youth, and only 4 in extreme old age. This result tends considerably to abate the ideas formed about the size of the mastodon, by those who imagined it to have had as many grinders as man, all equal to the largest. Buffon for instance, says, "The square form of these enormous grinding teeth, proves that they were numerous in the jaw-bone of the animal; and supposing only 6 or even 4 on each side, we may conceive what an enormous head it must have had to contain at least 16 grinders, every one weighing 10 or 11 pounds."—*Epoques de la Nature. Note Justif.* 9.

The jaws discovered since his time, correct these notions. We have now no proof that the great mastodon ever exceeded 12 feet in height, while the Indian elephant, according to Buffon himself, rises sometimes to 15 or 16.

In fact the very hot and dry temperature which prevailed on the antediluvian globe tended to stint the growth of every land animal in all moderately low latitudes, such as the mastodon inhabited; letting the elephant thrive comfortably only nearer the pole, as on the ancient fertile plains, where frozen Siberia now lies; while the tepid primeval ocean gave marvellous development to all its productions, from the polyparia and shellfish, to the megalosaurus and iguanodon.

The condyle of the mastodon's jaw resembles that of the elephant, whence also we may conclude against its having been carnivorous. The two sides of the lower jaw-bone *diverge* towards the chin in the mastodon, whilst in the living elephant they *converge* more or less, and in the fossil or Russian mammoth, they are almost *parallel.* Only the hog and hippopotamus resemble the mastodon in this particular. Its bony palate extends much behind the last tooth; the phacochère or wild boar of Ethiopia alone possesses a kindred structure. The pterygoid processes of its palate bones have a magnitude unexampled among quadrupeds. As there is no trace of an orbit on the anterior part of the zygomatic arch, the eye must have stood higher in the mastodon's head, than in the elephant's. The mastodon had also a proboscis like the elephant. Its greatest height to the saddle seat, was from 11 to 12 feet, and its length 15 feet; being lower and

longer in proportion, than our living elephants. The form of its feet bones, proves that it was not adapted for swimming and living much in the water like the hippopotamus. Its bones are in a better state of preservation, and fresher than any other of the fossil kind; which has been ascribed to the saline soil in which they are mostly found.

Of the other species of mastodon.—Grinders and other bones, have been found in many parts of Europe, particularly Tuscany, Simorre, Bavaria, Trevoux, from Sort near Dax, Asti in Piedmont, and many other places, which M. Cuvier refers with his well known sagacity to the species formerly enumerated. For the particulars I must refer to his great work, vol. I. p. 250.

The bones of the mastodon with narrow teeth occur in South America; and they furnished matter for marvellous recitals to the older Spanish writers. At Lima many of their grinders are preserved both in the public cabinet, and among private individuals, which pass for the teeth of giants. One of the localities of these bones, near Santa-Fe de Bogota, is called indeed the Giant's-Camp, (Camp-des Geants). M. Humboldt informs us that an immense heap of them lie buried there, impregnated with sea salt, at the great height of 1300 toises, about 8300 English feet, above the level of the sea.

The interesting questions whether any fossil remains of pachydermata exist in the diluvium of tropical Asia, and whether they agree with the recent species of these genera, or with the extinct ancient species, has been lately answered by the zealous investigations of Mr. Crawford, who has sent home

no less than seven large chests of fossil wood and fossil bones from the banks of the river Irawadi, near the town of Wetmasut, about half way between Ava and Prome, in latitude 21° to 22° N. To add to the interest of this discovery, two new specimens of mastodon were found, differing materially from every species hitherto described. On an examination of the structure of the teeth, this discovery will be seen to have still greater claims to attention; for it illustrates very beautifully the gradual shades of difference by which nature passes almost imperceptibly from one form to another, and helps to fill up the interval, which has hitherto separated the mastodon from the elephant.

On comparing the teeth of the mastodon latidens with those of the mastodon of the Ohio, (mast. giganteum,) we shall find the elevated points or ridges in the tooth of the former more numerous, less distant, and the interstices less deep than in those of the latter; in short we shall observe that the teeth begin to assume the appearance of those of the elephant. On advancing to mastodon elephantoides, we shall find all these features of similarity more strongly developed; the points and ridges are still more numerous, and the structure, were it not for the absence of *crusta petrosa*, (the *cortical*) becomes almost that of the tooth of the elephant. In both, though the teeth are formed upon the principle by which the tooth of the mastodon is distinguished from that of the elephant, the crown of the tooth wears away more like the tooth of the elephant than that of the other mastodons; and when worn, exhibits a surface not unlike that presented by the worn

tooth of an Asiatic elephant. These observations, says Mr. Clift, will not it is hoped be deemed out of place; for many a link in the chain, which the zoologist who confines himself to the study of living animals, seeks in vain, may be found in the relics of a former state of animal life. The size of M. latidens appears to have equalled, if it did not surpass that of the largest living elephant.—*Geol. Trans. Second Series, vol. II. p.* 370.

Mr. Clift finds that none of these Birman bones belong to the fossil elephant, but only to its companion animals of the diluvial loam, namely, the rhinoceros, hippopotamus, mastodon, and hog. Bones of two or three species of ruminants have been also detected, which resemble the ox, the antelope, and the deer; as also of the gavial, the alligator, and two freshwater tortoises, the *trionyx* and the *emys*.

The mastodon teeth come from animals of every age; and there are several fragments of ivory, belonging also probably to mastodon tusks. The remains of this animal are by much the most numerous, amounting to 150 pieces.

There are about ten fragments of the rhinoceros, two of a small species of hippopotamus, one of a hog, about twenty of ox, deer and antelope; about fifty of gavial and alligator; with twenty of emys and ten of trionyx. One of the fragments of emys is so large that the animal which owned it, must have been several feet broad. As the bones are impregnated with hydrate of iron, they are very dense, and in a state of perfect preservation; but none of them are silicified, though such a report was circulated. The district in which they were found is a range of barren hills, intersected by ravines, consisting of sand with beds of gravel occasionally cemented into a conglomerate by carbonate of lime, with hydrate of iron. Over the surface of these hills the fragments of bones and wood are scattered; sometimes quite bare; at others, half buried in the sand and gravel, while several pieces of the wood lie in the bottom of the ravines. About one-third of the bones have been slightly rolled; and all the rest have been broken to fragments, scattered, and buried by the action of the same waters which pro-

duced the diluvial sand and gravel, whence they have been exhumed and laid bare by rains and torrents.

Concretions of sand and gravel adhere to several of the bones, but they contain no traces of shells; differing in their mineralogical relations from all the specimens of rocks collected by Mr. Crawfurd, which belong to the tertiary and freshwater formations.

Mr. Crawfurd clearly shows that it is impossible to refer the situation of the bones, or the origin of the hills which contain them, to the action of the existing river. These hills are 60 feet above its highest floods. He observes also that the effect of its actual operations, is distinctly visible in the moving islands of mud and sand which abound along the course of the river, at the level of its highest floods, and in the great alluvial delta which begins a little below Prome, and extends to Rangoon and the gulf of Martaban.

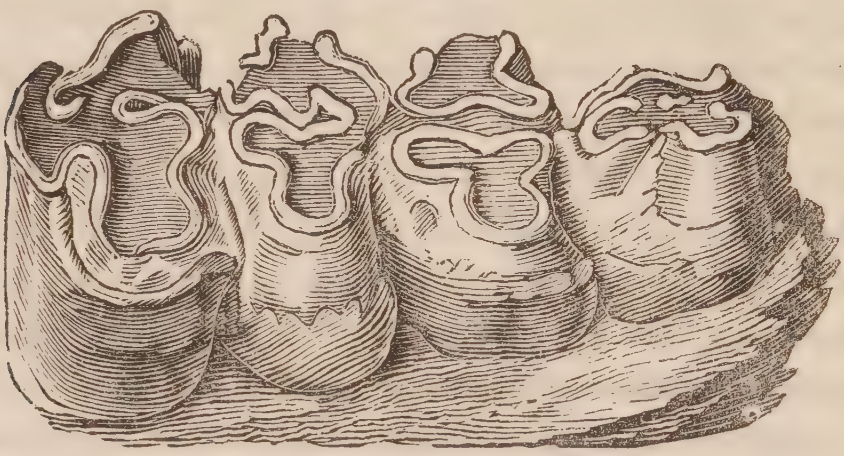
The recent bones and wood, which he observed dispersed in some of these islands, had no tendency to mineralize, but on the contrary were in a state of rapid decomposition.

From the facts above enumerated by Mr. Crawfurd, Dr. Buckland draws the following conclusions; that the Birman country contains not only the remains of fossil animals enumerated above, but also examples of the following geological formations, which may be regarded as identical with those of Europe; viz.:

1. Alluvium.
2. Diluvium.
3. Freshwater marl.
4. London clay formation and crag-limestone, *(calcaire grossier)*.
5. Plastic clay with its sands and gravel.
6. Transition limestone and gray-wacke.
7. Primitive marble and limestone.—*Geological Transactions*, 18*th April*, 1828.

III. *Fossil Hippopotamus.*—There is only one existing species of hippopotamus; but M. Cuvier has discovered the remains of two and probably of four fossil species. The first of these is so similar to the living species that he was puzzled at first to distinguish between the two; a second is nearly of the size of the wild boar, but in other respects, just a

miniature of the large species. The third is almost intermediate between the two preceding ones. Lastly, he has observed traces of a fourth, almost as large as the hog of Siam.



The above figure, $\frac{7}{9}$ of the natural size, represents a fragment of the upper jaw of a hippopotamus, containing two teeth, the last and second last molaris of the left side, in that state of dentition precisely, in which they may be most easily recognised by the trefoil-like lineaments of their crown. The original is now in the cabinet of M. de Drée at Paris.

Hippopotamus' bones are nearly as numerous in the upper *Val d'Arno* in Tuscany, as elephants, and more so than those of the rhinoceros. They are indiscriminately mixed with each other in the same diluvial strata, or sandy hills, which form the first ranges of the mountains surrounding that beautiful valley. A fine tusk has been exhumed out of the sands of the plain of Grenelle, near Paris. Hippopotamus bones have been found in *diluvium*, near Oxford, Brentford, and Walton in Essex; and in Kirkdale cave. By a skilful comparison of these bones with those of the living hippopotamuses, M. Cuvier has proved that the two skeletons differ nearly as much as the fossil elephants, and rhinoceroses, differ from those of our times.

IV. *The fossil Rhinoceros.*—This genus, extraor-

dinary as it must appear to those who contemplate it for the first time, stands somewhat less insulated among animals than the elephant. It is connected in a distinct manner, by its osteology, to the damans, tapirs, and horses; and among fossil forms, there are several *genera* which resemble it in certain particulars. The fossil bones of the rhinoceros, although less numerous than those of elephants, are not so in any very great degree. Both of them are found in the same countries, and in the same localities; but the teeth of the rhinoceros being less bulky, have not been so often recognised. Nor do these animals possess like elephants, those enormous ivory tusks, which could not be seen without exciting much attention. Hence, fewer fragments have been collected of the genus under review, and hence they have been less talked of by naturalists.

There are different species of the fossil rhinoceros, but the most remarkable, and that longest known, has its nostrils separated by a bony partition.

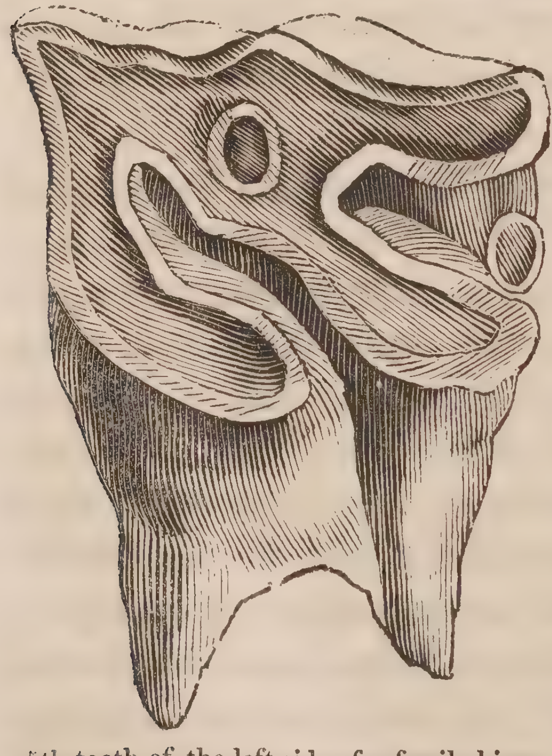
In 1668, in digging a well at Chartham, 3 miles from Canterbury, at a depth of 17 feet, the first noticed fossil bones of rhinoceros were found. But it was not till 1768, that Pallas, then appointed director of the Academy of Petersburg, found among its collection of fossil bones from Siberia, 4 skulls and 5 horns of rhinoceros. Having travelled through Siberia himself, he adduced, 15 years after the above date, a great multitude of new facts to the same purpose. In 1773, he published the narrative of the astonishing discovery of an *entire rhinoceros*, found with its skin, in December 1771, buried in the sand, on the banks of the Wiluji, a

river which runs into the Lena, below Jakoutsk, in the 64th degree of North Latitude. To this notice, he added the figure and description of a pretty complete fossil cranium.

Bones of rhinoceros have since been found in almost every part of Europe; near Quedlimbourg in Germany; Darmstadt on the banks of the Rhine, along with elephants' and ox bones; a skull in the territory of Worms; a skull at Weissenau near Mayence; at Strasbourg; near Cologne; a whole skull near Lippstadt in Westphalia; a heap of bones of elephants, rhinoceroses, and hyænas, between Osterode and Dorste; near Burgtonna in Gotha, teeth and bones of rhinoceros; in various parts of France; most abundantly in Italy, particularly in the Val d'Arno, besides a whole skeleton on a hill parallel to *Monte Pulgnasco*, not far from where M. Cortesi had also found before the skeleton of an elephant. In England such fossil remains are very common.

At Chartham, in the old locality, a fragment of an under jaw containing two teeth, was dug up in 1773. In the gravel pits of Brentford, a mile north of the Thames, immediately reposing on the London clay, were discovered in 1813 several fossil bones of elephants, hippopotamuses, stags, and oxen, described in the Phil. Trans. for 1813. The third figure of pl. IX. is, according to M. Cuvier, an upper grinding-tooth of a rhinoceros. Several bones of the same animal have been found at Walton opposite to Harwich. At Newham near Rugby in Warwickshire, there were dug out of a diluvial gravel mixed with clay resting on a bed of lias limestone, in 1815, two skulls, and other bones of rhino-

ceros, with 3 very large elephants' tusks, and some stags' horns. More lately at Lawton near the same village of Rugby, several other bones of rhinoceros were discovered in *diluvium*. In 1817, Sir Everard Home read to the Royal Society an interesting memoir on fossil bones of rhinoceros found by Mr. Whitby at Oreston near Plymouth, in a limestone cavern, 160 feet deep, in the solid rock. The proper mouth of that cavern, which was 45 feet long, had been probably filled up by the convulsions of the deluge. Here teeth, vertebræ, and other bones, belonging to 3 individuals, were found. Some rhinoceros' bones have also been detected in the caves of Kirkdale and Wirksworth, of the Crawley rocks near Swansea, and Paviland. To the above must be added, the bones found in Ava.



5th tooth of the left side of a fossil rhinoceros—little worn—natural size.

From a comparison of the whole facts, M. Cuvier concludes, that a large unknown species of rhinoceros, is found in a great number of places in Europe and Asia; the integrity of whose bones indicates that they have not been transported from a distance, but have been buried by a sudden revolution of the globe, which has destroyed the whole species. Its size was nearly the same with that of the living

rhinoceros. But there were 3 other fossil species; one of them much smaller, not equalling the tapir in size.

V. *The Elasmotherium.*—This is a genus of fossil animal of Siberia, discovered and described by M. Gothelf de Fischer, aulic counsellor of the emperor of Russia, and Professor at Moscow. Its teeth are very peculiar, showing its diet to have been more completely graminivorous than that of the rhinoceros; and more similar in this respect to the elephant and the horse. M. Cuvier considers it as forming an intermediate link between the horse and rhinoceros, but of the size of the latter. It had, probably, the aspect of a gigantic horse; and is thought by M. Cuvier to have been an astonishing animal.

VI. *Fossil Horse.*—The bones of this animal are almost as common in the diluvial strata as those of any other of the larger species; but they have been hitherto little attended to in the works on fossil remains. There are thousands of horses' teeth in the celebrated deposit of bones of elephants, rhinoceroses, tigers, and hyænas, discovered in 1700, near Canstadt in Wirtemberg. A similar assemblage was recently discovered at Thiede near Wolfenbüttel; at Fouvent in France; in the Val d'Arno; in the caves of Kirkdale, Mendip, Clifton, and Plymouth, and Paviland in England; in diluvial loam, near Oxford, Walton, and Lawford. M. Cuvier says he has been always struck with the fact that the really fossil-horse bones never attain to the magnitude of those of our great horses; remaining usually at the middle size of zebras and large asses.

He concludes that a species of the genus horse, served as a faithful companion to the elephants and the other animals of the same epoch, whose remains are now numerously scattered among the diluvial beds; and that there is no very marked difference between its bones and those of our living breeds.

VII. The daman, the tapir, and the rhinoceros, possess great osteological affinities, as well as the skeleton of the horse; but their differences are such as to allow of intermediate genera. These intervals, these chasms now left in the series, appear to have been anciently filled up by genera, of which nothing but the fossil remains are known to us; but whose teeth, feet, and other characteristic organs lean in part to the one, and in part to the other set of animals; yet differing from them as a whole.

Thus we find in the environs of Paris and elsewhere, the genus of the *palæotheriums*, which resemble the tapirs in their incisor and canine teeth, and especially in having nasal bones adapted to bear a proboscis; but with grinders like those of the rhinoceros and the daman.

In the same locality we observe the genus *anoplotherium*, which has also grinders akin to those of the rhinoceros and daman, the nose-bones of which are formed as in the greater number of quadrupeds; but whose incisor and canine teeth, as well as feet, are disposed in a singular manner in this class of animals. All its teeth form merely one uninterrupted series as in man, and its feet have only two toes like those of ruminants, without having their metatarsal and metacarpal bones united into one

body (canon) as they are in the above family. Among these various exuviæ we may discover some which appear to resemble the tapir more than any other genera, by the transverse and almost straight hillocks *(collines)* which stand in relief on several of their grinders; which M. Cuvier classes under the head of

VIII. *Gigantic fossil tapirs.*—Most of the bones referred by M. Cuvier to this genus have been found at Comminge near the river Louze and at Chevilly in France. He considers one species of this animal to have been 18 feet long, and 11 high, which makes it equal to elephants, and to the great American mastodon. Other individuals, those of Carlat and Chevilly must have been a little less; but they were still very formidable animals. It would appear that these gigantic tapirs date from the same epoch as the fossil mastodons and elephants; that they lived along with them, and were destroyed by the same catastrophe, since their bones are found in the same *diluvium*, and sometimes as at Chevilly and Avaray mingled *pele-mele* with theirs.

IX. *Fossil lophiodons.**—This is a genus of animals akin to the tapirs by their incisor and canine teeth, and by their size; but whose anterior and posterior grinders present some differences. It is doubtful if these animal remains belong to the diluvial detritus. M. Cuvier thinks that they should be referred to the superior regular strata, and are therefore of a prior date to the fossil elephants, mastodons, &c. Many of them have been found

* From the Greek; hillock-formed or crested teeth.

near the village of Issel, along the slopes of the Montagne-Noire, department of Aude, impasted in a very hard kind of pudding-stone, or alluvial sandstone, composed of siliceous grains of different colours, rolled and irregularly rounded, and bound together by a calcareous cement. A great portion of the bones were mutilated, and a greater number still had been rolled before being incrusted. Some are dyed black, others dun, and others a beautiful violet. Besides the bones of lophiodons, and paleotheriums, there have been extracted from that breccia, bones of crocodiles, bones of large turtles, probably of the genus *emydes*, and incontestible bones of the *trionyx* or soft turtle; circumstances the more remarkable as these different genera accompany one another almost constantly in the localities where they have left their exuviæ. The lophiodons occur very numerously in these recent conglomerates.

Their generic characters consist:

1. In 6 incisors and two canine teeth in each jaw; 7 molares or grinders on each side in the upper jaw, and 6 in the under, with a vacant space between the canine and the first molaris; points in which they resemble the tapirs.

2. In a third crest on the last under molaris; which is wanting in the tapirs.

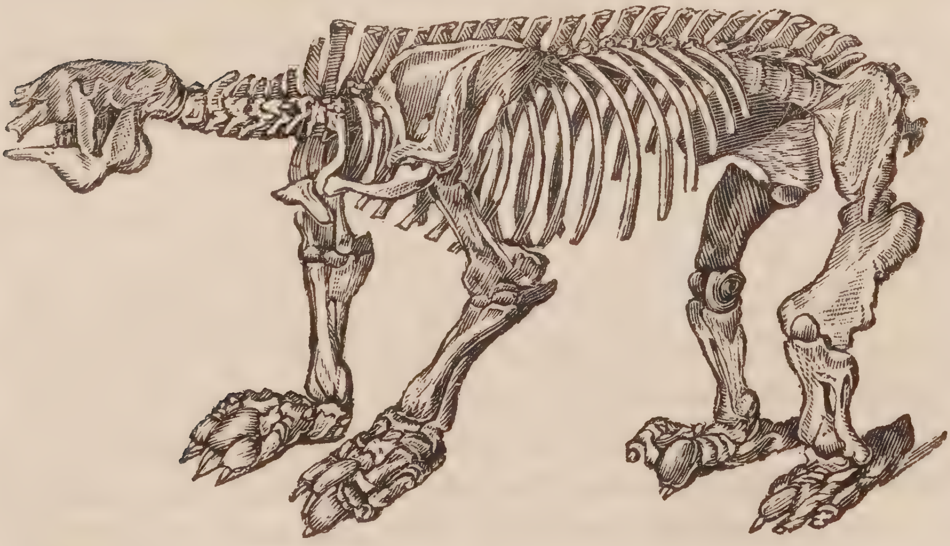
3. In the anterior grinders of the lower jaw having no transverse hillocks as in the tapirs, but presenting a longitudinal series of tubercles, or one insulated conical tubercle.

4. In the superior grinders having their transverse crests more oblique, thereby akin to the rhinoceros,

from which they differ by the absence of the hooks in their crests.

What is further known concerning the osteology of the lophiodons indicates manifest affinities with the tapirs, rhinoceroses, and in some particulars, with the hippopotamuses. There are several species of them; the whole remains of which are found enveloped in beds containing exclusively freshwater shells; associated with amphibious animals, such as the crocodile and trionyx, which now inhabit the freshwaters of hot countries; but in a few places, these remains are covered with a stratum undoubtedly of marine formation.

X. *Of the Megatherium.*



This is of all the fossil animals of very great size, the most lately discovered, and hitherto the rarest; and yet it is the one whose osteology was first completely understood, in consequence of all its bones being found assembled in one place, and of their being immediately mounted into a skeleton with the utmost care. To the praise of the Spaniards it

must be said, that they first gave this useful lesson, since followed by Mr. Peale in the American Mastodonte, and by Mr. Adams in the Siberian elephant.

From the publication of Don Joseph Garriga, it appears that Spain has been long in possession of considerable portions, of at least three different skeletons. The first and most complete is that in the Royal Cabinet of Madrid. It was sent thither in the course of September 1789, by the Marquis de Loretto, viceroy of Buenos Ayres, with a notice intimating that it had been found in excavations made on the borders of the river *Luxan*, a league south-east of the city of the same name, which itself is 3 leagues to the west-south-west of Buenos Ayres. The soil in which it was found is raised only about 36 feet above the level of the water. A second skeleton arrived in 1795, at the same Cabinet, sent thither from Lima; and a third, which father Fernando Scio of the pious schools possessed, had been presented to him by a lady returning from Paraguay. These two cannot now be found.

The first animal of 1789 was mounted up by Jean-Baptiste-Bru *prosecteur* of the Royal Cabinet of Madrid, who delineated the entire figure of it, and its different parts in five plates which he got engraved, and published with a minutely detailed description. In 1818 the megatherium was inspected by a Livonian anatomist and a German draughtsman conjointly, who published at Bonn in 1821 an exact description and representation of the skeleton.

The first glance at its head lays open to us the most marked relations with the structure of the sloths and their aï species of Buffon. The most striking point of resemblance is the long descending apophysis on the cheek, placed at the anterior base of the zygomatic arcade. This is as long in proportion in the aï, as in the megatherium, but in the latter it has a more upright direction. The fossil has also the arcade in one piece, whilst it is discontinuous in

both species of sloths even when full grown; however traces may still be seen in the arcade of the megatherium of the structure peculiar to sloths.

The long oblique process which rises from the upper edge of the arcade exists also in the aï. The multitude of holes and little canals with which the front part of the fossil muzzle is riddled, would allow vessels and nerves to pass through proper for cherishing a considerable organ like a proboscis, which must however have been very short, seeing the length of the neck. As the head has a moderate size and carries no tusks, a long neck was not so injurious as it would be in the elephant.

The grinder teeth amount to four on each side, both of the upper and under jaw, and like those of sloths, have a prismatic form and crown traversed by a furrow. The sloths have one tooth more in the upper jaw. The former have two roots, the latter a single one.

If the number of seven vertebræ seen in the neck of this skeleton be real, as the analogy of other quadrupeds would make us readily believe, the megatherium will differ much in this respect from the sloth aï, which deviates in its nine cervical vertebræ from all kown quadrupeds. There are in the megatherium sixteen dorsal vertebræ and consequently sixteen ribs on each side, and there are three lumbar vertebræ. This is exactly the number in the aï. The relative proportion of the extremities is not the same as in the sloths, which have the forelegs double the length of their hind legs. Here that inequality is much less. On the other hand the disproportionate thickness of the bones of the thigh and leg, which begin to be visible in the sloth, the armadillo, and especially the pangolin or short-tailed manis, is carried in the fossil skeleton to an excessive degree, the thigh bone having a length only double of its greatest thickness, which makes it grosser than any animal known, even the great mastodonte of the Ohio. This general disposition of the extremities leads us to judge that this animal had a slow and regulated gait, and that it advanced neither by running nor by leaping, as animals which have their forelegs shorter than the hind ones, nor by creeping, like those with relatively long hind legs, as the sloths; which the megatherium otherwise so much resembles.

The shoulder blade alone would indicate the family of the animal, and the genus to which it is most allied. It has not only, on a

great scale, the same proportions as the sloths, but it exhibits also the round hole observable in this genus, as well as in the middle ant-eater *(tamandua)*; and further it possesses in common with the sloths this character unknown elsewhere among the *mammifera*, that its acromion process is prolonged in form of an arc, and goes forwards to join itself with the coracoid beak, affording through it an articulation with the clavicle. The presence of clavicles removes the megatherium considerably from all the quadrupeds which might be confounded with it on account of its huge size, as the elephant, rhinoceros, and all the large ruminating animals, none of which possess these bones.

The humerus (shoulder-bone) of the megatherium is very remarkable by the breadth of its lower end, arising from the great surface of the ridges placed above its condyles. We thereby see that the muscles attached to it, and which served to move the palm and the toes, must have been very considerable;—a new proof of the great use this animal made of its anterior extremities. In like manner this great breadth of the bottom of the humerus is also found in the ant-eater, which is known to employ its enormous claws for suspending itself to trees, or for digging up the solid nests of termites. In it, the breadth is three-fifths of the length, while it is only one-half in the megatherium;—the proportion of the scaly ant-eater with a long tail or the *phatagin (Manis tetradactyla Lin.)*. In the rhinoceros this breadth is only one-third, and in the elephant one-fourth of the length. In the ruminating animals, which make almost no use of their toes, these ridges nearly disappear.

Thus the affinities of our fossil begin to extend. From a head and a shoulder-blade almost exactly like a sloth, we have come to a humerus nearly of an ant-eater.

The basin resembling in its enormous size, that of the elephant and rhinoceros, indicates that the megatherium had a large belly in accordance with the form of its grinder teeth, and shows that it lived on vegetable substances. The thigh bone is too large for comparison with any other animal. The nearest is that of the rhinoceros, but this differs in having a third trochanter, which is wanting in the fossil thigh, giving it a close analogy in form with that of the pangolins.

The inspection of a skeleton so complete, and

fortunately preserved, enables us to form conjectures somewhat plausible on the nature of the animal to which it had belonged. Its teeth prove that it lived on vegetables, and its robust fore-feet, armed with sharp claws, testify that it was chiefly their roots which it sought after. Its magnitude, and its talons, supplied it with abundant means of defence. It was not swift in running, but this was unnecessary, as it had no occasion either to pursue or to fly. It would therefore be difficult to find in its organization alone the causes of the final destruction of the genus; and yet if it still exists, where can it be? How can it have escaped all the researches of hunters and naturalists? Its analogies approximate it to different genera of the edental or toothless family of animals. It has the head and shoulder of a sloth—a creature possessing both tusks and grinders; while its limbs and its feet exhibit a singular mixture of characters belonging to the ant-eaters and the armadillos. It has no analogy whatever with the felis or tiger tribe. The wood-cut represents exactly the form of its skeleton, which is fully 13 feet long from the muzzle to the coccyx, and 9 feet high at the saddle-seat. The term megatherium signifies a huge wild beast.

XI. The *megalonyx* is another large fossil animal of the edental family, of which, however, only a few bones were found at a depth of two or three feet, in a cavern of the county of Green Briar, in the south-west of Virginia. The district is calcareous, and consequently similar to that of the mineral strata of Germany and Hungary, where the famous

fossil bears' bones abound. This animal has been carefully compared with the *megatherium* by M. Cuvier, and shown to be of a different species. The *megalonyx* is so called from the magnitude of its claws.

Besides the above marked genera of extinct ancient animals there have been found in our diluvial soils, fossil bones of the hyæna, tiger, bear, wolf, fox, weasel, ox, deer, hog, and castor. But as these also mostly occur along with some others, such as the rabbit, water-rat, glutton, and birds, in the bone caverns of calcareous rocks, and the fissures of the breccias on the Mediterranean shores, we shall consider all the remaining victims of the deluge, in our survey of

Antediluvian dens, and rocky fissures.—The former contain the bones of the various animals which used them as places of residence or retreat; the latter, of such as accidentally fell into them, and perished. The caverns lie for the most part in the older calcareous formations, such as the transition, mountain, and Alpine limestones; but the fissures abound in less ancient rocks. Besides the fossil pachydermata, already brought before us in the *diluvium*, we shall here meet with the following genera; the bear, hyæna, tiger, wolf, fox, weasel, ox, deer, rabbit or hare, water-rat, mouse, glutton, castor, and birds. On the antediluvian forms of these animals, we shall offer a few preliminary observations.

I. *Stag.*—The stag with gigantic antlers is the most celebrated of all the fossil ruminants, one which naturalists unanimously regard as a species

unknown in the living state. Its remains are more abundant and complete in Ireland, than in any other country; but a few have been found also in England, France, Germany, and Italy. They occur in a marly *diluvium* similar to that in which the bones of fossil elephants so frequently lie. M. Cuvier shows that the head and antlers of this animal, distinguish it from the elk and every other species of the deer tribe.

The organic remains of Etampes, found buried in sandstone strata of that district, is a fossil species, akin to the rein-deer, of which fragments also occur in the cavern of Bregue, department of Lot. Many other exuviæ besides these bones and antlers have been collected in the same places, as bones of the elephant, ox, and some *carnivora*, the rhinoceros, and horse. Fossil remains of deer are not uncommon in the bone caverns of England and Germany. There are many also found in modern *alluvia* and peat bogs, which are referrible to postdiluvian races.

II. *The fossil ox.*—The form of the skull can alone determine the species of this genus, which is much less numerous in the fossil kingdom than the stag. Hitherto only 3 have been found; one resembling the aurochs or bison, another the common ox, and a third the musk buffalo of Canada. Their resemblance to the living species is so close, as to make it very difficult to define their distinctions. From an elaborate comparison of the fossil remains, with the anatomy of the actual races, M. Cuvier draws the following conclusions:

That the genus ox existed at the same epoch with the extinct elephants and rhinoceroses:

That there were then at least two species of ox; one with limber extremities like the bison; and another with thicker limbs like the bull or buffalo:

That the skulls similar to our domesticated ox have not been found in an authentic manner except in peat-bogs or other very superficial beds. It is therefore not impossible that these may have a more modern origin than the elephants' and rhinoceros' bones, and that they may have belonged to the wild stock of our tame ox.

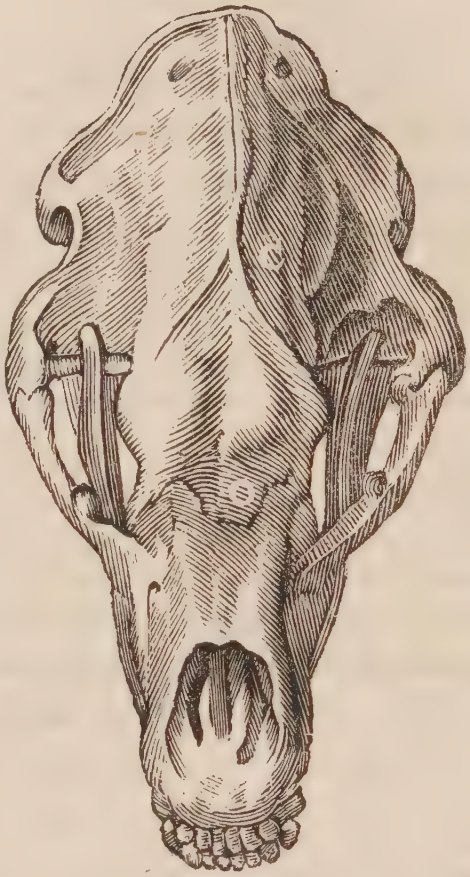
No fossil bones have been found which correspond to any variety of the Indian or Cape buffaloes; consequently, if the fossil species belong to the same breed as our living ones, they must have been inhabitants of cold countries.

The skulls similar to those of the musk buffalo of America having been noticed only 3 times on the coast of Siberia, doubts remain concerning them, not only as to the identity of the species, but also whether they be truly fossil, or accidentally imported from America on rafts of ice.

III. *The fossil bear.*—The teeth so thickly strewed in the German caves, of which thousands have been sold for centuries back, under the name of the fossil unicorn, are bears' teeth perfectly similar, as to the incisors, the canine, and great molares, with those of our northern bears, but their size indicates peculiar species, being larger, by at least one-fourth, than the teeth of our living bears. These cavern teeth are in general less worn, and have their enamel and all their prominences more entire than those of our living races; proving that the extinct species were more exclusively carnivorous.

The skulls of the cavern bears belong to at least two species.

1. The great skulls with convex fronts.



One of these is represented in the wood-cut. On comparing it with the skulls of living bears, the former may be readily distinguished by the marked elevation above the root of the nose, and the two convex bumps on the forehead at O, as well as by the great prominence, and quick convergency, of the temporal ridges at C; whereas in the skulls of living bears this coincidence takes place one-third nearer to the occiput. This rising of the ridges denotes the very superior strength of the temporal muscles inserted into them, corresponding to the greater size of the animal.

2. The great skulls with less convex fronts.

This species differs also in some essential points from the living species.

3. There are smaller skulls in the caves, more akin to those of modern bears, but which M. Cuvier also refers to the ancient epocha.

The first form constitutes the *ursus spelæus* of the German archæologists; the second has been called *ursus arctoides;* and the third, *ursus priscus.*

The principal characters therefore of the skulls of the great fossil bear, are, 1st, the strong elevation, in the forehead immediately above the root of the nose, and the two convex bumps a little higher up; 2d, the great prominence of the temporal ridges, their rapid convergency seen at C in the wood-cut, and the length and height of the sagittal suture running from C to the hind-head. The black bears both of Europe and America resemble the fossil ones, in the form of the ridges more than the polar bears do; but they differ more by the flatness of their forehead. The temporal ridges of the black bears unite into the sagittal at nearly one-half the distance between the orbits and the occiput; but in the fossil bear, at one-third of this interval, as may be observed at C. To these differences, and to those presented in the teeth, we may add the difference of size. The largest heads of our brown bears measure 14½ inches from the spinous process of the hind-head, to the incisor teeth; and the largest of our black bears of Europe measure a little less. But the largest of the fossil heads with projecting frontal bones measure in the above direction 18½ inches, being as nearly as possible a fourth more; which corresponds to the magnitude indicated by the molar teeth. And as the polar bear is usually less than our great brown bear, Camper had reason to say, that the fossil bear exceeded it by no less than a third.

IV. *The fossil hyæna.*—A hyæna has certainly abounded in that ancient world whose ruins we now explore. Its bones occur not merely in the same receptacles which contain so many relics of the bear, but also, in the *diluvial* beds where such multitudes of elephants lie buried. The largest deposit of hyæna bones observed at first, where their numbers, says Cuvier, may be deemed marvellous, was in the cave of Kirkdale, so admirably described by Doctor Buckland. A far greater deposit, however, has since been discovered at Torquay.

Outside view of the jaw-bone of a fossil hyæna, found at Kirkdale, copied from Dr. Buckland's engraving, plate xviii. fig. 2. Phil. Trans. for 1822. It is about a third larger than that of the living hyæna. The formidable canine tusk is seen to the left, then four molar teeth, the last and largest of which is called the great *carnivorous (carnassiere).* This tooth resembles the corresponding one in the spotted hyæna, more than in the striped. But the spotted hyæna has the posterior knob (talon) of that tooth much less than the striped and the fossil hyæna. The great thickness of the teeth harmonizes well with the delight and facility with which hyænas are known to gnaw and devour bones.

The fossil hyæna seems to have been more powerful than the existing species; its limbs were somewhat thicker and shorter; and its anatomy differed in some minute particulars.

V. *Fossil felis, or tiger and lion family.*—A very large animal, and another less, both belonging to the genus *felis*, have left their exuviæ in the caverns and *diluvium;* the former has been called *felis spelæa*, the latter *felis antiqua.* It is therefore incontestable that fossil species of tiger or lion, lived at the same period with the fossil bears, and retired into the same caverns, where the bones of both genera lie promiscuously, along with bones of hyænas; but the felis tribe was less numerous. M.

Goldfuss says that in twenty years, during which time, several hundred bears' skulls were extracted from the caves of Muggendorf, no more than 15 skulls of hyænas were found, and only 3 or 4 of the *felis tribe;* but he states that at Gaylenreuth, the separate teeth and bones, and fragments of the skulls of tigers or lions are not rarer than those of hyænas.

The inverse proportion holds in the Kirkdale cave; where the hyæna remains are far more numerous than those of the other *carnivora;* while the *felis* exuviæ are very scarce, and there is hardly a vestige of the bear. The bones of the fossil *felis* are in general stronger than those of the living animals of this tribe, and in some particulars of their osteology specifically different.

VI. A few fossil bones have been found belonging to the genus *Canis.* These have been referred to the wolf or dog; the osteology of these animals being nearly the same; a few to the fox and to a species the size of the polecat; and some to the weasel.

VII. M. Sœmmering discovered in the cavern of Gaylenreuth a skull of the genus *ursus gulo* or glutton, whose only species now known, inhabit exclusively cold regions.

" The glutton and the hyæna, the rein-deer and rhinoceros, in the same caverns, as we observe at Gaylenreuth and Breugues; the bison (aurochs) and the elephant, in the same *diluvium* as we find in the valley of the Arno, reveal certainly a state of the earth very different from what we witness, or

imply in these animals a temperament opposite to what their kindred species now display."*

On these suggestions I would merely observe, that the fossil vegetable remains exhumed in high latitudes, in Melville Island and Siberia, as well as in the strata of Germany, France, and England, establish beyond all possibility of a doubt the far higher temperature which prevailed in these regions on the antediluvian globe, than at the present day.

OF THE BONE CAVERNS.

All the great calcareous formations, the mountain limestone, as well as the more modern, are excavated in many directions into large vaults and fissures, several of which have been long admired on account of their sparry roofs and stalactitic projections. In the stratified limestone of Crete, lies the famous labyrinth. Through the whole island, says Tournefort, there is a world of caverns; especially in Mount Ida, there are holes you may run your head in, bored through and through, and very deep perpendicular chasms also abound. In the limestone districts of England we have likewise a vast number of such vaults and subterranean rivers, as in Derbyshire, where Mr. Farey enumerates 28 remarkable caverns, and as many open fissures, locally called shake-holes, or swallow-holes, from their swallowing up the streams that cross the limestone districts of that country. The fissures descend from the surface to a very considerable depth, and often expand into vaults or communi-

* Cuvier, Ossemens Fossiles, Tom. IV. p. 487.

cate laterally with caverns. Many such excavations ingulph rivers in the limestone formations of the Mendip hills and South Wales, in the west of Ireland, Carniola, and North Ameriea.

The bone caverns of Germany are quite analogous. Nothing, says M. Cuvier, is more truly curious than the new theatre into which I am about to transport my readers. Numerous grottoes, brilliantly decorated with crystalline stalactites of every form, succeeding each other to a great extent through the body of the mountains, communicating together by openings so narrow that a man can hardly proceed by crawling on his hands, yet with their floors all bestrewed with enormous heaps of bones of animals of every size, form undoubtedly one of the most remarkable phenomena which the fossil kingdom can present to the meditations of the geologist, more especially when we consider that this scene of mortality is repeated in a great many places, and through far distant lands. No wonder then that these vaults of death have become objects of research to the ablest naturalists, and that their bony relics have been often described and figured. Prior to such philosophical inquiries, however, these bones were famed among the populace; who, as usual, added many imaginary prodigies to the natural wonders which they had seen. The bones were long dug up and sold, as bones of the *fossil unicorn*, to the apothecaries, on account of some singular virtues which they were reputed to possess; and there is no doubt that this strange traffic contributed mainly both to the investigation of old caves, and to the discovery of new ones.

The most anciently celebrated cavern is that of Bauman in the Duke of Brunswick's dominions, in the district of Blankenbourg, to the south of the village of this name, in a hill which forms one of the exterior slopes of the Hartz mountains towards the east. The general direction of the cave is from east to west, but the entrance looks to the north. Although it soon expands into an ample vault, the mouth is narrow, and can be entered only by crawling. The first grotto is the largest; from which there is a descent into the second of 30 feet, at first by a narrow gallery through which we must creep, and then by going down a ladder. This grotto is the richest of all the German caves in stalactites of every form. The passage to the third grotto is at first peculiarly difficult, compelling the visitor to advance on all fours; but it afterwards enlarges, exhibiting on its walls stalactites of the most fantastic shapes. From this vault, there are two lateral dilatations which constitute the third and fourth grottoes as delineated in the plan of the *Acta Eruditorum.* At the extremity of the passage, it is requisite to reascend in order to reach the entrance of the proper third cavern, which opens out like a gateway. Beyond this third grotto, there is said to be another passage terminating in two small caves.

The Rev. Dr. Buckland has published in his Reliquiæ Diluv. an accurate section of Bauman's Höhle in the Hartz. The first or grand chamber, is from 40 to 50 feet in diameter, with stalactites on various parts of its roof. Its floor is covered with a bed of diluvial loam containing some bones and

pebbles, and having on its surface a few fragments of stalagmite, left by the labourers along with large blocks of limestone, fallen from the roof. The intermediate expansion between the first great grotto and the last, or lower vault, is floored with a thick crust of stalagmitic spar, covering a large accumulation of loam and large pebbles, through which are dispersed great quantities of bears' bones. The lowest cavern is of a similar nature.

A second grotto, nearly as famous as the first, and at no great distance from it, is called the Unicorn's cave. It lies at the base of the castle of Scharzfels, in that district of the electorate of Hanover, called the duchy of Grubenhagen, on nearly the last southern slope of the Hartz mountains. The entrance is ten feet high and seven wide. There is a vertical descent of fifteen feet into a kind of vestibule, whose roof gradually slopes downwards till at the end of 60 paces, the visitor is obliged to crawl. After a long passage, he meets successively with 3 or 4 caverns, which the country people say extend nearly two leagues into the mountain. The bones taken from this repository belong to bears, the hyæna, and a tiger or lion. Doctor Buckland, who explored it, represents its roof as hung with stalactites; but much of the carpet of stalagmite, as having been destroyed and removed by those who dug up the bones. Over the solid floor of the cave a bed of brown earth or diluvial loam is spread, interspersed with angular fragments and rounded pebbles of limestone, and a few remaining bones and teeth. The undermost

vault, still undisturbed, is filled with the same *diluvium* copiously stuffed with bones.

The chain of the Hartz offers some other caverns of less notoriety, though quite analogous.

The cave of Hartzbourg, under the castle so named, and above Goslar to the south, is mentioned by Behrens; that of Ufftrungen, in the lordship of Stolberg; and a third called *Diebes-loch,* or the robbers' hole. *Biels Höhle* nearly opposite Bauman's seems to contain no bones, and is accordingly omitted by M. Cuvier. A section exhibiting its singular zig-zag windings is given by Doctor Buckland; which serves also to explain how the diluvial deflux scooped out the present entrances into these two caves, while the old ones were obliterated by the convulsions concomitant on the deluge.

In Hungary there are similar bone caves, called the Dragon-Grottoes by the country people, from an idea that the osseous relics appertain to that fabulous animal; but they belong to the great cavern-bear, *ursus spelæus.*

Of all the German caves, however, the richest in bony relics are those of Franconia, of which Esper, an ecclesiastic of the territory of Bayreuth, has given a very detailed description in a specific treatise; and more lately, M. Goldfuss, professor of natural history at Bonn, has published a valuable work on the same subject, entitled, *The Environs of Muggendorf.* The greater number of the grottoes here lie in a small peninsula, formed by the river Wiesent, which falls into the Regnitz, a tract belonging to the great basin of the Mein. The principal cavern, however, the astonishing Gaylenreuth, lies on the outside of this kind of peninsula, on the left bank of the Wiesent, to the north-west of the village from which it takes its name. Its gateway, through a vertical rock, is 7½ feet high, and looks to the east.

The first grotto turns to the right, and is upwards of 80 feet long. It is divided into four parts by the unequal heights of the vaulted roof; the first three are from 15 to 20 feet high; whereas, the fourth is only from 4 to 5. On the bottom of this part, and on a level with the floor, there is an orifice only two feet high, which leads into the second grotto. This runs first southward for 60 feet, being 40 wide and 18 high; it then turns to the west through a space of 70 feet, becoming gradually lower till its altitude is only 5 feet. The passage to the third grotto is very incommodious, winding through several corridors. It is thirty feet wide, and only five or six high. The loam of the floor is stuffed full of teeth and jaw-bones. Near the entrance to it, is a gulf of 15 or 20 feet, into which visitors descend by a ladder. After going down, they arrive at a vault 15 feet diameter by 30 feet in height; and on the side on which they descend, is a grotto all bestrewed with bones. By going down a little further still, they fall in with a new arcade which conducts to a grotto 40 feet long, and a new gulf 18 or 20 feet deep. Even after this descent, another cavern presents itself 40 feet high, quite covered with bones. A passage now of 5 feet by 7 leads to a grotto 25 feet long and 12 wide; then alleys, 20 feet long, conduct into another cave 20 feet high; and finally, a grand grotto expands, 83 feet in width, and 24 in height, more copiously furnished with bones than any of the rest. The sixth and last grotto runs in a northerly direction, so that the whole series of caverns and corridors, describes nearly a semicircle.

A rift in the third grotto, disclosed in 1784, a new grotto, 15 feet long by 4 wide, where the greatest number of hyænas' and lions' bones were found. The opening was much too narrow to have allowed these animals to have entered by it. A peculiar tunnel which terminated in this small grotto, afforded an incredible number of bones, and large skulls quite entire.

Professor Buckland gave, in the Phil. Trans. for 1822, a section of this cavern, sketched by himself in 1816. See our Plate VII. and its explanation at the end of the Volume. Here we may observe particularly an enormous mass, wholly composed of bones enveloped in stalactites, forming thus a peculiar osseous breccia. The Professor represents

on his plate of this cave, in his Reliquiæ Diluvianæ, on the floor of the first grotto, a bed of diluvial loam, mixed with pebbles, angular fragments of limestone, bones and teeth; the latter being of course more abundant in the remoter grottoes, which have been less excavated for the German apothecaries. A crust of stalactite is still perfect over some portions of the floors.

The cavern of Gaylenreuth is the one whose bony relics are most completely known, in consequence of the researches which have been so long carried on with regard to them by men of eminent science, such as Esper, Humboldt, Ebel of Bremen, Rosenmüller, Sœmmering, Goldfuss, &c. as well as by the numerous and rich collections which these researches have furnished. From the examination which M. Cuvier has made of the chief of these collections, the bones composing them, belong, in the proportion of three-fourths, to bears, of two or three species of the genus; next to which are those of hyæna, wolf, fox, glutton, polecat, or some kindred animal. He also observed, but in smaller number, some bones of *herbivora*, and particularly stags, fragments of which are now in the possession of M. Ebel. It would even appear from a passage in M. Sœmmering's work, that a parcel of bones of an elephant's skull had been extracted.

According to M. Rosenmüller, there are likewise bones of men, horses, oxen, sheep, stags, roebucks, mules, badgers, dogs, and foxes; but the whole of these are shown by accurate inspection of their localities in the cavern, and their state of preservation, to have been deposited at a much more

recent era than that of the bears, tigers, and hyænas.*

The small peninsula opposite to the above, offers several other caverns, as the Schœnstein, or the *beautiful rock*, which contains 7 contiguous grottoes; the Brunnenstein or *Rock of the Fountain*, contains bones incrusted with stalagtite; and the Holeberg, or *hollow mountain*, in which 8 or 10 grottoes form a suite of 200 feet, with two outlets. Bones of bears like those of Gaylenreuth are here found in different lateral recesses, along with some bones of stags and swine. The Wizer-loch, so named from an ancient Slavonic god that was there worshipped, the most gloomy cavern of the whole country, is more than 200 feet long, lies in its higher grounds, and has afforded a few vertebræ. The Wunder höhle, having a circuit of 160 feet, was made known only in 1773. Lastly, the cavern of Klanstein, composed of 4 grottoes, and 200 feet in depth, has furnished a few bones in its third chamber, and still more at its furthest end. We may add to the above, the Geiss-knok, or the Goat-cave, discovered in 1793, in which M. Rosenmüller found two human skeletons already covered with stalactite, a process which may be accomplished in less than a century.

The country surrounding this small peninsula is pierced with several caverns, besides that of Gaylenreuth, as the grottoes of Mokas, Rabenstein, and Kirch-ahorn, three villages, the first being to the south, the two others to the north-east of Gaylenreuth. Formerly bones were found in the first. The last cavern is known in the country by the expressive name of Zahn-loch, or tooth cavern, and the peasants were wont to regard these bones as medicinal. Rosenmüller and Goldfuss found here some teeth of bears and

* Description de l'Ours des Cavernes, p. 2.

tigers. There are two other grottoes in the lands of the same village, one of which Schneider-loch (taylors' hole), afforded an elephant's vertebra. The cave of Zewig, hard by Waschenfeld, on the borders also of the Wisent, is nearly 80 feet deep; and is said to have contained skeletons of men and wolves.

All these hills, scooped out into caverns, and so close to each other, seem to form a small chain, interrupted only by streamlets, and which graduates into the loftier chain of the Fichtelberg, where the highest mountains of Franconia rear their heads, and whence flow down, the great rivers, Mein, Sale, Eger, Naab, with several smaller streams.

It deserves to be remarked, that according to both Rosenmüller and Buckland, the hills to the north of the Wiesent, contain not a single fragment of bone, while those to the south of it, are well stocked with them.

There was discovered in 1799, a cavern remarkably situated, which connects in some measure those of the Hartz with those of Franconia. It is the cave of Glucksbrunn, in the bailiwick of Altenstein, in the territory of Meinungen, called the cave of Liebenstein by Rosenmüller, as it lies on the road to this bathing place. The limestone out of which it is hollowed, rests on bituminous schist, whence as it ascends, it reposes its upper beds on primitive rocks. This limestone is of variable hardness and fracture, and contains marine petrifactions, such as pectinites, echinites, &c.

In cutting through a road, an opening was discovered, from which a very cold wind issued; in consequence of which, the duke of *Saxe-Meinungen* caused further excavations to be made. A passage of 20 feet, conducted into a grotto 35 feet long, from 3 to 12 wide, and 6 to 12 high, closed at the end with a great mass of rock, which was mined away. After working for two years, they opened

up and cleared out a series of grottoes linked together, with floors alternately rising and falling. The whole terminated in a spot through which a run of water flowed; but different lateral clefts would lead us to suppose the existence of several other caves which have not been explored, forming altogether a species of labyrinth.

The bottom and sides of this cavern were coated with the same kind of loam, that lines all the others, but blacker. The bones were in considerable number, and were dyed of the same colour, but only two tolerably entire skulls have been extracted. One of them belongs to M. Cuvier's first species of fossil bears.

Caverns like these also exist in Westphalia.

In the county of *La Mark*, at *Sandwich*, two leagues from Iserlohn, there is a grotto which furnished, 25 years ago, a very large quantity of bones. A part of these was sent to Berlin; and another has remained in the country, among the hands of individuals; but hitherto no special description has been given of them.

If we glance our eye over a general map of the country, it will not be difficult to perceive a certain continuity in the mountains, where these curious caverns lie. The Crapack mountains are associated with the mountains of Moravia, and those of Bohemia, termed *Bœhmerwald*, and both together form barriers between the basin of the Danube, and the basins of the Vistula, the Oder, and the Elbe. The Fichtelberg again separates the basin of the Elbe, from that of the Rhine. The Thuringerwald and the Hartz continue to bound the basin of the Elbe, and disjoin it from that of the Weser. Between these different chains, there are no considerable intervals. The caverns of Westphalia are the only ones, which do not so obviously run into the rest.

Very recently, fossil bones have been discovered in a cavern which lies more to the south, and rather on the back of the Alps, looking towards Italy. It is the cave of Adelsberg in Carniola, on the great

road from Laybach to Trieste, almost equidistant between these two towns. The whole of that district is excavated with grottoes and caverns, which have produced even on the surface of the ground a great many hollowings, which give a singular appearance to the country. Several of these caverns have been long celebrated among naturalists.

That of Adelsberg is usually visited by travellers, because it is contiguous to the highway, and because it absorbs a river called the *piuka* or *poike*, which forms within it a subterranean lake, whence the stream again bursts forth on the north side, under the name of Unz. An aperture discovered by Chevalier Löwengreif in 1816, in one of its sides, at 14 fathoms high, admitted him into a range of grottoes of immense extent and incomparable beauty, from the lustre and varied forms of their stalactites. A few of the grottoes, however, have been long well known. M. Volpi of Trieste, affirms that he has advanced more than three leagues into these caverns, almost in a straight line, and was stopped only by a lake, which rendered his passing further impracticable. About 2 leagues from the entrance he discovered bones of animals, since found to be those of the great fossil bears.

The cave of Kirkdale in Yorkshire, had the good fortune to be visited by men of science, and particularly by Professor Buckland soon after it was laid open, in consequence of which its organic remains have been carefully collected and accurately described. The little river Hodge-beck, loses itself under ground in the neighbourhood, much as the Piuka does near Adelsberg.

It is scooped out in the interior of one of the calcareous hills which flank the vale of Pickering on the north, the waters of which fall into the Derwent. The substratum of the valley is blue clay, like that which at Oxford and Weymouth reposes on a similar limestone,[*] containing subordinately, beds of imflammable bituminous shale, such as that of Kimmeridge in Dorsetshire. The rock perforated by the cave is referrible to that portion of the oolite formation which in the south of England, is known by the name of the Oxford oolite and coral rag; its organic remains are identical with those of the Heddington quarries near Oxford, but its substance is harder, more compact, and more interspersed with silicious matter, which forms in the limestone, sometimes throughout its coral line exuviæ, irregular concretions, beds and nodules of chert. The more compact beds of this limestone resemble the younger Alpine limestone of Meillerie and Aigle in Switzerland; alternating with and passing gradually into those of a coarser oolitic texture. Both varieties are disposed in beds from one to four feet thick. The cave lies in one of the compact beds, placed between two others of the coarser oolitic variety; the latter of which varies in colour from light yellow to blue, while the compact beds are dark gray passing into black, are extremely fetid, and full of corals, and spines of the echinus cidaris. The compact portions of this oolite, partake of the property common to compact limestone of all epochs and formations from the transition to the newer Jura; of being perforated by irregular holes and caverns in all directions.

It was in the summer of 1821 that quarriers working here discovered by accident an opening which had been closed with rubbish, and covered over with bushes and grass. It lies about 100 feet (a late observer who measured it, says it is only 30), above the neighbouring streamlet; and it may be entered to 150 or 200 feet, but a person can stand upright only in a few places, on account of the stalactites which project from its roof. On the floor of the cavern, a carpet of diluvial loam is spread, about a foot thick, stuffed full of bones, as at Gaylenreuth. This loam and the bones interspersed through it, are invested in different places, or penetrated with stalactite, especially near the spot where lateral fissures intersect the rocks.

By far the greater number of the bones belong to hyænas of the same species as that of the German caverns; but there are also remains of several other animals, large and small, estimated by Doctor Buckland to represent 21 species.

According to the fragments which M. Cuvier has obtained by the kindness of the Doctor, and Messrs. Salmond and Gibson, the bones without any doubt, belong to the *elephant*, *rhinoceros*, *hippopotamus*, *horse*, *ox* (of the common ox proportions), *deer*, *hares*, water-rats and common rats. There are also bones of some other *carnivora*, particularly of the tiger, wolf, fox, and weasel. All these bones and teeth are aggregated in the loam, broken, and gnawed, displaying still the prints or traces of the teeth which broke them. Even the excrement pallets or balls have been recognised; and shown to resemble those of the

hyæna, by an accurate comparative analysis of Dr. Wollaston.

The bones of a species of rat *(hypodæus)*, nearly of the size of the water-rat *(mus amphibius Lin.)* exist in such profusion in the Kirkdale cave, that a piece of loam can hardly be lifted from the bottom, which is not replete with them. There are also plenty of bones of the field mouse.

The hills containing these caves are all of analogous composition; being calcareous, very productive of stalactites, which under a thousand varied forms line the walls and narrow the passages. The bones are here in nearly the same condition, as in all the other bone caves; detached, dispersed, partially broken, but never rolled, and consequently not drifted from a distance by the waters. They are a little lighter, and less solid than recent bones, yet as to their true animal nature, very little decomposed, still combined with gelatine, and not at all petrified. An indurated loam, which may be easily broken or pulverised, including also some animal matter, occasionally black-coloured, forms their natural envelope. This paste is sometimes impregnated and covered with a stalactitic crust white as alabaster; a glaze of the same nature invests the bones in different places, penetrates their natural cavities, and causes them sometimes to adhere to the sides of the cavern. The stalactite now and then acquires a reddish tint, from the intermixture of animal matter. At other times, its surface is black; but these changes are obviously the results of modern circumstances, totally independent of the cause, which brought the bones into these excava-

tions. The stalactite may be now seen progressively advancing, to embrace in different points, groups of bones previously untouched.

This mass of earth, impregnated with animal matter wherever it occurs, whether in Germany or England, envelopes indiscriminately the bones of every kind ; and with the exception of a few found at the surface of the floor, which have been carried thither at much later periods, and are still distinguishable by their inferior state of decomposition, the whole must have been interred together in the same manner, and by the same causes. In this earthy paste we find diffused among the bones, at least in the grotto of Gaylenreuth, fragments of a bluish marble, with all their angles rounded or smoothed, as if they had been rolled. They bear a striking resemblance to those which enter into the composition of the osseous breccias of Gibraltar and Dalmatia.

Finally, the most interesting part of the phenomena is that the more remarkable species of the bones, are identical over a space of about 550 miles (more than 200 leagues). Three-fourths and upwards belong to bears, which are no longer to be found in the living state. One-half, or perhaps two-thirds, of the remaining fourth, have been traced to a species of hyæna, which is equally unknown at the present day. A smaller number may be referred to a species of the genus tiger or lion, and to another species of the wolf or dog family. Lastly, the smallest specimens proceed from various little *carnivora*, as the fox, the polecat, or at least kindred species. The Kirkland, Torquay, and

Lunel caves, however, form notable exceptions by affording very few bones of bears, and exhibiting a great predominance of hyænas among the *carnivora*.

The species so common in the diluvial *detritus*, namely, the *elephants*, the *rhinoceroses*, the *horses*, the *oxen* or *bisons*, and the *tapirs*, are very rare in the bone-caves of Germany; and there are some of these animals even which no person has yet detected there. A few bones of deer constitute the whole of the herbivorous relics yet described. In this respect, again, the Kirkdale cave differs widely from the others, since it abounds as much in the bones of the great and little herbivorous animals as in those of the carnivorous. All the greater *pachydermata* of the diluvian gravel, the elephant, rhinoceros, and hippopotamus, are found at Kirkdale; as well bones of oxen, deer, down to rats and birds. No marine animals of any species have left their bones either in the Kirkdale or German caves.

These bones of *carnivora*, so numerous in the caverns, are rare in the *diluvium*. The hyæna alone occurs in it, in a certain quantity at Canstadt, near Aichstedt, and in some other places; a few relics of bears also appear in Tuscany and Austria, but their relative proportion is greatly less than in the caverns; and besides, there is abundant circumstantial proof that these different animals have lived together in the same country, and belonged to the same epoch. This important fact, says M. Cuvier, appears to me perfectly established by Dr. Buckland.

There are only three general causes which can be possibly imagined to have introduced the bones in

such quantities into these vast subterranean vaults; 1st, they are either the remains of animals which dwelt and died peaceably in these chambers; or, 2d, of animals which inundations and other violent causes carried in; or, 3d, of the animals which had been enveloped in the stony strata, whose watery solution produced the caverns themselves, but the soft parts were dissolved away by the agent that scooped out the mineral substance of the caves.

This last hypothesis is refuted by the circumstance, that the strata themselves in which the grottoes are excavated contain no bones; and the second, by the entire state of preservation of the smallest prominences of the bones, which precludes the idea of their having been rolled. Even if some bones are worn smooth, as Doctor Buckland has remarked, they are so only on one side; which at the utmost merely proves that something has abraded and polished their surface in the bed where they lay. We are therefore compelled to resume the first supposition, and to regard these caverns as the dens of antediluvian *carnivora*, which dragged in thither and devoured the animals, or parts of animals, that fell in their way.

Dr. Buckland has shown that the hyænas' bones of the Kirkland cave are no less broken and gnawed than those of the herbivorous class; whence it appears that these creatures, by force of ravenous appetite for bones, devoured those of their own species like the hyænas of the present day. The hyænas, indeed, are known to attack each other, during life. There are, therefore, few physical propositions established on a larger or sounder

induction than that of the Kirkdale and Torquay caves having been dens occupied by hyænas in antediluvian times. Those persons who may hesitate to adopt this conclusion on account of any preconceived notions about the habits of living hyænas, and the aspect of their dens, will find every rational doubt removed by perusing an interesting letter on the subject from Captain Sykes, on military service near Bombay, published in the 2d volume of the new series of the Edinburgh Philosophical Magazine, p. 378.

This conclusion is moreover confirmed by the animal nature of the earthen floor of the caves in which the bones are impasted. M. Laugier has analysed that of Gaylenreuth with his well known precision; and found the following ingredients.

1. Lime mixed with a little magnesia and combined with carbonic acid,	32
2. Carbonic acid and a little moisture,	24
3. Phosphate of lime,	21.5
4. Animal matter and water,	10.
5. Clay coloured with a trace of manganese,	4
6. Silica coloured with iron,	4
7. Oxide of iron, combined perhaps with a little phosphoric acid,	3.5
Loss,	1.0
	160.0

It is very certain that the establishment of these animals in the caverns is long posterior to the epocha, at which the extensive mineral strata were deposited, not only of the mountains that contain the caverns, but of even those of much more modern formation. As for the stalactites of the

caves, M. Goldfuss observed a stratum of it covering the names of MM. Esper and Rosenmüller, inscribed at their visit only thirty years before.

In March 1826, Dr. Buckland visited the bone cave of Lunel near Montpellier, situated in compact *calcaire grossier*. In working a freestone, the side of the cavern was accidentally laid open, and considerable excavations have since been made in it, at the expense of the French government, for the purpose of extracting its animal remains that lie buried in mud and gravel. A rectangular vault has thus been exposed, nearly 100 yards in length, and from 10 to 12 in width and height.

Many of the bones bear marks of being gnawed by the teeth of *ossivorous* animals; and there is an extraordinary abundance of balls of *album græcum* in the highest state of preservation.

M. Marcel de Serres has published a list of the animal remains contained in this cavern, which differ but little from those of Kirkdale; the most remarkable addition being that of the beaver and the badger, together with the smaller-striped, or Abyssinian hyæna.

In Oct. following, the Dr. visited also the grotto of Oiselles near Besançon, in France, for the purpose of applying to it, the method of investigation which his experience in other caverns had taught him to adopt with success in the pursuit of fossil bones. This grotto is of vast extent, nearly a quarter of a mile in length, and made up of a succession of more than thirty vaults or chambers, connected together by narrow passages, and running almost horizontally into the body of a mountain of

Jura limestone, on the left bank of the Doubs near Besançon.

The only entrance to the grotto is by an irregular aperture about the size of a common door, in the slope of the hill about 60 feet from the river. The abundance and beauty of the stalactite in many parts of this cavern, have rendered it one of the most celebrated and most frequented in France; but before Dr. Buckland, no one had ever sought for bones beneath the crust of stalagmite, which in most of the chambers covers the floor.

On breaking for the first time through the stalagmite, the guides were much surprised to find the Doctor's prediction verified, as to the existence of a thick bed of mud and pebbles, beneath what they had considered to be the impenetrable pavement of the cave, and still more so, to see that in every one of the only four places which he selected for investigation, this diluvium was abundantly loaded with the teeth and bones of fossil bears. These lay scattered through the mud and gravel, in the same irregular manner as the bones of bears lie in the caves of Franconia and the Hartz, and are, like them, the remains of animals that lived and died in these caverns, before the introduction of the diluvium. They were found nowhere in entire skeletons, but dispersed confusedly through the mud. They were from bears of all ages, and none bore marks of either having been rolled by water, or gnawed by the teeth of hyænas. Of this last named animal, Dr. Buckland found no traces in this cave, in the few spots which he examined. He says the best rule to follow in pursuit of antedi-

luvian remains in caverns, is to select the lowest parts in which any diluvium can have accumulated, and there dig through the stalagmitic crust, and seek for teeth and bones in the mud and pebbles that lie below. Their antiquity may also be tested by their property of adhering to the tongue (happer) in consequence of their loss of gelatine, without the substitution of mineral matter; a property which the bones found in the Roman graves and Druidical tombs of England do not possess.

This cave has been since explored by the French naturalists, and a report made of some of its contents by Baron Cuvier to the Academy of Sciences. The bones in one of its chambers belong entirely to the cavern bear, *ursus spelæus*, without intermixture of any other animal remains whatsoever. In some adjoining chambers, hyæna bones have been found, along with those of tigers, and other *carnivora*, with a few bears' bones. In other caverns, which contain many hyænas' bones, those of herbivorous animals occur more numerously, all marked as at Kirkdale with gnawed prints of the hyænas' teeth. M. Cuvier concurs with the Doctor in thinking that these excavations were hyænas' dens, in which the last of these animals were drowned by a diluvial inundation, which has choked up the mouths of the caves with gravel and clay. The grotto of Oiselles lies at the foot of the Jura mountains, and consists of a great many separate chambers of considerable dimensions.—*Annales de Chim. et de Phys. Oct.* 1827.

A bone cave called Kent's Hole near Torquay

in carboniferous limestone, discovered lately, has brought unequivocal confirmation to Doctor Buckland's theory of the Kirkdale phenomena. The condition of the hyænas' teeth, the number and variety of animals, and the circumstances that accompany their mangled remains, are precisely the same in both dens; the only difference being that the Torquay cave is twenty times more extensive than the Yorkshire one; and the animal exuviæ in like proportion. The superficial crust of stalagmite, and the bed of mud which forms the matrix of the broken bones and teeth beneath it are also proportionately thicker. There is also *album græcum* excrement, as at Kirkdale, and stumps of gnawed horns of deer; and the bony bases of horns of rhinoceroses, but no horns of this animal, although more than a hundred of its teeth have been already found; along with the teeth of many infant elephants, numberless bones of horses, elks, deer, and oxen, gnawed bones, and jaws of hyænas, with their single teeth and tusks; the teeth and tusks of bears, tigers, wolves, and foxes; and of an unknown carnivorous animal, as large at least as a tiger, the genus of which has not yet been determined.

Of more than a thousand bones, or rather fragments of bones, that have been collected in Kent's Hole, not fifty have been found entire, the extremities and condyles of the cylindrical bones having been gnawed off, before they were imbedded, along with the accompanying splinters and teeth, in the mud and gravel conglomerate of the cave. The softer portions of the bones are invariably removed, and

marks of gnawing and fracture impressed, such as the living hyænas, at Exeter Change, are known to make on the ox bones on which they feed.

Doctor Buckland considers the cave of Kühloch, as more remarkable than all the rest in the neighbourhood of Rabenstein, and indeed the only one he has ever seen except that of Kirkdale, in which the animal remains have escaped disturbance by diluvian action. The interior of Kühloch has the capacity of a large church. Its floor is covered, to an average depth of 6 feet with black animal dust, constituting altogether a mass exceeding 5000 cubic feet, with broken fragments of bones interspersed. That black earth seems to be pulverised bone, in a dry state, rising in powder under the feet, and is used by the peasants as a fertilising manure. Dr. Buckland computes on reasonable grounds that in the single vault of Kühloch the remains of at least 2500 bears are accumulated, a number which may have been supplied in the space of 1000 years, by a mortality at the rate of two and a half *per annum*. For some other judicious speculations on the singularities exhibited by this cave, the *Reliquiæ Diluvianæ* may be consulted, p. 138.

In the same instructive work, several additional localities are mentioned of bone-caverns in England. The cave of Hutton, a village in the county of Somerset, at the foot of the Mendip hills, contained bones of elephants, horses, wild boars, two species of stags, oxen, a skeleton almost entire of a fox, and the metacarpal bone of a great bear.

The cave of Derdham Down, near Clifton, hard by Bristol, afforded bones of the horse.

In the cave of Balleye, near Wirksworth, in the county of Derby, elephants' teeth were discovered so long ago as 1663, some of which are still preserved.

The Dream cave, at the hamlet of Callow, also near Wirksworth, is very remarkable. Here, in the midst of a mass of diluvium, almost all the bones of a rhinoceros were found in very good condition, which have been carefully collected by the proprietor, Mr. Gell.

The cave of Nicholaston, on the coast of Glamorganshire, between the bay of Oxwich and the cape of Worms, which marks the entry of the Bristol Channel, deserves notice. There have been found in it, an elephant's tusk and molaris, as also several other bones of elephant, rhinoceros, horse, bear, hyæna, fox, wolf, ox, stag, rat, bird, and even the skeleton of a woman and her bone-pins. But several of these objects are evidently seen to be modern.

M. Goldfuss, in the New Memoirs of the Academy of the Curious of Nature for 1823, has extended his researches on the fossil bones of Westphalia and Franconia. He estimates that the proportion of species in them is nearly such : that for 800 of the cavern bear (*ursus spelæus*), there are found 60 of the northern bear (*arctoides*), ten of the *ursus priscus*, 30 gluttons, 25 tigers or lions, 50 wolves, and 25 hyænas ; which is just the inverse proportion of the contents of the Kirkdale cave in Yorkshire.

In the cavern of Sandwich, and in a smaller adjoining cavern, called *Henri*, there have been found at different times, besides fragments of bones

of bears, a skull and portion of the jaw bone of a hyæna, bones of gigantic stags, of a stag like the common one, of a third species the size of a deer, a skull of a glutton, a fragment of the under jaw-bone of the hog, teeth and occiput of the rhinoceros, but no bones of tigers, lions, or wolves.

The bone caverns discovered in cutting down the transition limestone rocks of Oreston for the purpose of making the break-water off Plymouth, were the subjects of three interesting communications from Mr. Whidbey, to the Royal Society; one in 1816, one in 1820, and one in 1822. At the date of the last, the whole mass of rocks was nearly quarried away. He then states, that "the joints of the rock were not so close, but that water might drop down into the cave; and about these joints some stalactites were found in small pieces. *I have not seen any thing to encourage the idea, that the cavern had a communication with the surface since the flood;* the present state of the quarries *shows nothing like it.*" We have in the same paper some valuable observations on the nature and appearance of the bones, by Mr. William Clift. In the Oreston cavern, discovered in 1816, although the greatest care was taken to collect all the bones contained in it, those of the rhinoceros alone were found. In the caves opened in 1820, one contained bones and teeth of the bear; while another contiguous cavity, of apparently coeval formation, contained only bones of a deer or antelope. In the caverns discovered in 1822, the bones of animals of several distinct genera were found, namely, the bos, the deer, the horse, the hyæna, the wolf, and the fox. These

cavities, however, communicated with each other, and the bones of the different graminivorous animals were found mingled together in the same cavity; but those of the carnivora at a considerable distance from each other; the bones of the hyæna having been discovered in a cavern, and those of the wolf and fox in a gallery. The only specimen in this large assemblage which bears any apparent marks of teeth, is a portion of the radius of a young wolf, which, in two or three places on its surface, has the impression of the incisors and canine teeth of some small animal of the size of a weasel. Some additional specimens of the jaws and teeth of the hyæna, the wolf, and the fox, were discovered in one of the caverns; from which cavity indeed, all the bones of the wolf have been derived.

A discovery of fossil teeth, and other bones of hyænas, with those of the horse and ox, was made in June 1827, in the extensive stone quarries of Boughton, about 3 miles south of Maidstone in Kent. They were all found nearly together in one of the numerous cracks or fissures (locally called rents) that intersect, in this place, the beds of Kentish rag, which consist of limestone and coarse flint, dispersed in planes of irregular thickness through a matrix of sand and sandstone. Its geological position is in the lowest region of the green sand formation, immediately above the Weald clay. The fissures cut through the strata from the bottom of the quarries to the surface, and are filled with diluvial loam. The bones appear to have been drifted to their present place at the same time with the diluvial detritus of loam and stony fragments, among

which they lay, occupying a position precisely similar to the bones of hyænas and other animals that were discovered in the fissures of the breakwater limestone rock, near Plymouth, imbedded in similar diluvial loam and pebbles.

The open fissure in Duncombe Park, lately examined by the Doctor, deserves remark, on account of the illustration which it affords of the manner in which the bones of antediluvian animals may have been accumulated by falling into similar fissures,—now filled up with diluvial mud and pebbles. This fissure seems of postdiluvian origin; being a great irregular crack or chasm, in the solid limestone rock, which forms a steep and lofty cliff on the right side of the valley of the Rye. It is almost concealed by overgrown bushes, and being nearly at right angles to the edge of the cliff, presents a pitfall across the path of animals passing that way. Into this chasm, the Doctor descended, and found the skeletons of dogs, sheep, deer, goats, and hogs, lodged at various depths on the lateral ledges. Now, such fissures undoubtedly existed on the antediluvian earth, and probably in much greater abundance than since the grand aqueous revolution, which must have filled up many of them with its *detritus*. There is therefore no reason why the then existing animals, should not have fallen into them, and have perished; particularly when we consider that it is the habit of graminivorous animals, such as those which have left their bones in the breccia fissures of the Mediterranean shores, to be constantly traversing the surface of the ground in every direction in pursuit of food, they must be peculiarly liable

to the accident of falling into any imperfectly closed chasm that lies in their way. Thus we have an explanation of the comparatively rare occurrence of the remains of beasts of prey in those osseous breccias of the antediluvian fissures, although they also perished in them occasionally, as dogs still do in the open fissure of Duncombe Park.

On the Bone Breccias of the Mediterranean coast.—At Gibraltar, Cette, Antibes, Nice, Uliveto near Pisa, Cape Palinurus, Corsica, Sardinia, Sicily, Dalmatia, Cerigo, and in the Veronese, *curious bony Breccias*, are observed filling up the fissures of calcareous rocks. In all these different and distant localities, the conglomerated fragments of bones are nearly the same. They are relics chiefly of ruminant animals, mixed with a few lions' teeth and exuviæ of other animals. The pieces of bone are impasted in a red earthy concretion resembling highly burned bricks, but spongy in texture from innumerable porous cavities of various size, which are bestrewed occasionally with a sparry incrustation. As the bones are not pressed together, the concretion which contains them must have been progressively deposited round them, as they fell into the rifts of the rocks. The bones have been in general broken to pieces before receiving their crust of spar; and are entirely dislocated from their organic arrangement in the animals; but they exhibit no signs of having been rolled.

The *stony* fragments of the breccia or conglomerate, are coarse-grained limestone (*saccharoid*), of a dark gray colour, containing now and then veins of white spar; and appear to have been rolled.

Their size varies from that of the fist to a small grain. The hollow bones are also lined with a similar stalactitic crust, yellowish, and of greater or less thickness. The bones themselves seem as if calcined by the loss of their albumen. They are very white, but still so hard, as to resemble petrifactions. Teeth have retained their enamel in a pure white form. The casts of shells belong to land snails; of sea-shells there is no trace.

The bones do not belong to our existing species of ruminants. In the bone rock of Gibraltar, so well described by Major Imrie in the *Edin. Phil. Trans. vol. IV.*, M. Cuvier found a species of hare, and probably a species of deer; neither of them now known in Europe. The rock of Cette is analogous to that of Gibraltar; being calcareous, and full of fissures filled up with bony breccias.

Five kinds of animals have been detected here by M. Cuvier; hares of the size and form of living ones; other hares one-third smaller; gnawers very similar to the field mouse; birds of the size of the wagtail; and serpents as large as our common snake. The bones of hares are most common; and they appear to M. Cuvier undistinguishable from the existing breed of wild hares, though he cannot venture to pronounce them the same, for their osteology is not nearer than that of the North American or Egyptian hares, which must be held to be different species from the European. The subgenus of *mus*, and the small tribes of which it consists, beginning with the *ondatra* or great musk-rat of America, and terminating with our small field mice, are distinguished from the other rats, by their teeth, to the

number of three, in all without roots, and composed through their whole height of triangular or rhomboidal prisms, whose edges are respectively parallel to the lateral faces of the prism. In the ordinary rats which are less exclusively herbivorous, the crown is short, tuberculous, and when it is worn so as to resemble a little that of the field-mice, its lowness, and the speedy division of the tooth into roots, enable us to recognise it.

From the bony breccia of Antibes, M. Cuvier has extracted a part of the lower jaw of a ruminant approaching in size to a moderately large fallow deer, and a very characteristic back grinder of a great horse. In the breccia of Nice, he found a portion of lower jaw of a sheep or antelope of middle size; several molar teeth of deer of different kinds; a first and last grinder of a large ox, imbedded in the red cement; the lower portion and condyle of a femur of a ruminant; a considerable piece of the hind foot of a species of stag; and distinct bones of a kind of horse of the size of a coach horse.

The gnawers so common in the other breccias of the Mediterranean shores, are rare at Nice. The tooth of a lion and a panther have been detected; also remains of a land tortoise, more akin to the *testudo radiata* of New Holland than any other.

In the osseous breccias of Uliveto near Pisa, M. Cuvier distinguished a tibia of a large ruminant, the jaw bone of a hare, and jaw bones of a species of fallow deer.

The Cape of Palinurus, which Virgil has engraved on the memory of every classical scholar,—

> O nimium cœlo et pelago confise sereno
> Nudus in ignota, Palinure, jacebis arena—

is a promontory on the coast of the kingdom of Naples, in the district extending from the gulf of Salernum to that of Policastro. M. Cuvier has obtained from its breccia, an upper part of the tibia of a stag, of intermediate size between a common deer and elk, and the under anterior molaris of a ruminant.

The breccias of Corsica are similar to the preceding. We find the same reddish cement, enveloping angular fragments of granular limestone, some snail shells, and innumerable parcels of bones,

with interstitial spaces, subsequently filled up or besprinkled with stalactitic crystals. M. Brogniart considers the stony fragments of the conglomerate, as transition limestone, the only old calcareous formation of the island, which immediately underlies the tertiary strata. M. Cuvier has found in this breccia a complete skull of a hare, which he refers to the tail-less hare, or *argali* of Siberia, called by him *lagomys*, which the *muffoli* of Corsica and Sardinia indeed closely resembles. He also detected an enormous quantity of bones of a species of gnawers, very like those of a water-rat; probably the same with the fossil field-mouse of Cette.

In the osseous conglomerates of Sardinia, have been found in a single specimen, the size of the fist, numerous bones of the field-mouse family, and of four other species of small gnawers, indicating a zoology quite different from what this country presents at the present day. A species of *lagomys* has been also detected. Fragments of the *sorex fodiens*, a species of water rat, have been likewise seen here. In conglomerates so richly stored with bones, what discoveries might be made, were there resident naturalists who could explore them for a few months on the spot!

From Palermo in Sicily, M. Cuvier had a piece of conglomerate which afforded him the forepart of the lower jaw of a horse, containing 6 incisors, belonging to an individual from 6 to 7 years old; and the lower condyle of a humerus of a stag, of intermediate size between that of Canada and our common deer.

The breccia of Dalmatia is probably the most extensive of all, stretching along the whole coasts of Venetian Dalmatia, and even much further towards the south. Its structure and aspect are the same as that of Gibraltar. All the bones hitherto extracted by Cuvier belong to ruminants, impasted in the ordinary reddish cement.

Doctor Buckland shows with his wonted sagacity, that the red cement of the osseous breccia, is an earthy loam, differing merely in colour from that which fills the caves and fissures of the rocks of the German caves, and constitutes the diluvial loam on their bottom. The consolidated state of the breccia, is due to the stalactitic infiltrations of calcareous

waters. This also has happened to much of the German cave loam. It appears that besides the bones of extinct species of animals, found in the fissures, and imbedded in their breccias, there are other bones of postdiluvian origin; both sets the remains of animals which had fallen into the crevices and perished there; only the first set are agglutinated by the diluvium and calcareous infiltration. Professor Buckland has shown analogous phenomena in the fissures of many of the English limestone rocks, as at Oreston, near Plymouth, and Duncombe Park.

Comparison of the Osseous Breccia, with the bony loam of the Caverns.—Mr. Fortis describes the breccia of Dalmatia, and some of the islands, as occurring both in vertical and horizontal cavities of the limestone, visible in clefts and fissures along the shores, and in caves in the interior of all the islands and coasts of Illyria. The bones are usually imbedded in the red ochreous cement, dispersed and broken. This mass of earthy loam, differs only in colour from that which fills the caves and fissures, and composes the superficial diluvial loam in Germany. Its consolidated state may be referred to stalagmitic infiltrations as we have formerly said. "At the north extremity of the mountain" of Gibraltar, says Major Imrie, "the concretion (of reddish calcareous cement) is generally found in perpendicular fissures; the miners there employed on the fortifications, in excavating one of those fissures, found at a great depth from the surface two skulls (not human). This concretion varies in its composition, according to the situation where it is

found. At the extremity of Prince's Lines, high in the rock which looks towards Spain, it is found to consist only of a reddish calcareous earth, and the bones of small birds cemented thereby. The rock around this spot is inhabited by a number of hawks, that in the breeding season nestle here, and rear their young; the bones in this concretion are probably the remains of the food of those birds. At the base of the rock below King's Lines, the concretion consists of pebbles of the prevailing calcareous rock. In this concretion at a considerable depth under the surface, was found part of a *green glass bottle*."*

These phenomena prove that a formation of analogous breccia is still going on. In the case of the Mediterranean breccias, as well as in the caves at Plymouth, the introduction of the loam and pebbles may be justly ascribed to diluvial action superinduced upon bones and angular fragments, that had fallen into the cavities whilst yet open, in the period preceding the last general inundation of the earth. "The uncovered parts of the rock," says Major Imrie, "expose to the eye a phenomenon worthy of some attention, as it tends clearly to demonstrate, that however high the surface of this rock may now be elevated above the level of the sea, it has once been the bed of agitated waters. This phenomenon is to be observed in many parts of the rock; it consists of pot-like holes of various sizes, hollowed out of the solid rock, and formed apparently by the attrition of gravel or pebbles, set in motion by the rapidity of rivers or currents in the sea. One of these which had recently been laid open I examined with attention, and found it to be five feet deep, and three in diameter; the edge of its mouth rounded off as if by art, and its sides and bottom retaining a considerable degree of polish. From its mouth for three and a half feet down, it was filled with a red argillaceous earth, thinly mixed with minute parts of transparent quartz crys-

* Edin. Phil. Trans. vol. IV.

tals; the remaining foot and a half to the bottom, contained an aggregate of water-worn stones which were from the size of a goose's egg to that of a small walnut, and consisted of red jaspers, yellowish-white flints, white quartz, and bluish-white agates, firmly combined by a yellowish brown stalactitical calcareous spar. In this breccia I could not discover any fragment of the mountain rock, or any other calcareous matter, except the cement with which it was combined. This pot is 940 feet above the level of the sea."

The red argillaceous earth forms the diluvial matrix of the bones in the caves and fissures immediately below; and the pebbles lodged with it on the summit of an insulated and precipitous mountain of limestone, are analogous to the blocks of Mont Blanc granite lodged on the high slopes of the Jura mountains; both having been forced up into their present places by the deflux of the deluge.

All these circumstances concur to establish an identity of time and manner in the formation of the osseous breccia that fills the fissures and caves of Gibraltar, &c., with that of the conglomerate loam, which occurs in the caves and fissures of Germany and England. Had the mud and pebbles been introduced into the caves before they were inhabited, they would have formed the lower stratum of the floor, over which the animal exuviæ would have been strewed; a condition totally different from the reality. The bones are indiscriminately distributed throughout the diluvium of mingled loam, sand, and pebbles, forming a paste, which the deeper we descend into the caverns, becomes thicker and thicker, till in the lower regions and under-vaultings, it chokes up the whole rocky excavation, thus affording the most graphic traces of the deluge, pouring down its debacle. That the bones were not washed into these vaults, from the open surface of the earth, is proved by the fact, that while every cave contains nearly the same proportion of

pebbly *detritus*, the occurrence of bones is limited to a small number; and in these they are crowded in such enormous quantities, and are so distributed as to demonstrate their pre-occupancy of the chambers. Nor has there been a succession of these mighty cataclysms; for there is only one crust of stalagmite, covering one agglomeration of gravel and bones; whereas on the former supposition, alternate strata would have been found.

The appearances in the Oreston caves near Plymouth, assimilate them more with the fissures of Gibraltar and Duncombe Park, than with the Kirkdale and other antediluvian dens. There was in the former, a nearly perpendicular hole, containing bones quite untouched by violence of any kind, lodged in irregular heaps in the lowest pits, and in recesses along the lateral enlargements of the hole, mixed with mud, pebbles, and fragments of limestone, in a manner precisely similar to the osseous breccias of the Mediterranean shores. Professor Buckland therefore concludes that the animals had fallen during the antediluvian period into the open fissures, and there perishing, had remained undisturbed in the spot on which they died, till drifted forwards by the diluvian waters to their present place in the lowest vaultings with which these fissures had communication. The wolves and hyænas may have either fallen by accident like the horses, oxen, and deer, into natural pitfalls in the Oreston rocks, or have recklessly leaped into them to devour the dead carcasses of the graminivorous animals. The large proportion of the latter animals to the carnivorous is quite consistent with this

hypothesis. In the districts of mountain limestone in Monmouth and Glamorganshire, the cattle have to be protected from such accidents, by the erection of walls round the open crevices.

The *lamantine* and *dugong* are two large cetaceous animals somewhat similar to seals, which now frequent, the former, the coasts of South America and Africa, the latter the Indian seas. They are both graminivorous, living on sea-weed, are accordingly furnished with grinders in their jaws, and never recede far from the shore, but sometimes advance into the mouths of rivers. Some bones of the lamantine have been extracted from a coarse shell limestone on the banks of the little river Layon, in the department of the Maine-et-Loire, as also in several other parts of France. M. Cuvier infers that it is very certain that an animal of the lamantine genus—a genus now peculiar to the torrid zone, dwelt in the ancient sea, which has covered the lands of Europe with its shells at a period posterior to the chalk formation, but anterior to that in which the gypsums were deposited, when the palæotheriums, and their contemporary genera lived in these latitudes.

Fossil Dolphins.—In 1800, M. Cortesi of Piacenza, collected some bones of the elephant and rhinoceros on the summit of Mount Pulgnasco, one of the hills which descend from the lofty Appenines towards the plain of the Po. They lie almost on the surface. Parallel to Mount Pulgnasco, to the east, and separated from it by the small stream called Stramonte, there is another hill much lower named Torazzo, from the remains of an old tower, and

composed, like the base of Pulgnasco, of a bluish clay, filled with sea shells. In this hill, about 120 feet above the Stramonte, M. Cortesi, attracted by a vertebra which had been brought to him from this place, made excavations, and discovered the nearly entire skeleton of a dolphin; a success which excited him to very zealous researches since that time. The fish to which that skeleton belonged must have been about thirteen feet long. M. Cuvier considers it to be of a different species from the dolphins now known to naturalists. Fossil remains of another dolphin have been found at Sort, a village in the department of Landes, two leagues from Dax, buried in a bed of broken shells and other marine productions. The whole length of the animal when alive must have been 9 feet; and it seems also to differ from existing species. Some other fossil fragments of dolphins have been found in other places.

CHAP. VII.—THE PRESENT EARTH, AND ERA OF ITS EMERGENCE.

The original dry lands having been upheaved from the circumfluent abyss, prior to the creation of the animal tribes, were truly primitive formations, affording naturally to the husbandman a dense and stubborn soil. But the mineral strata formed under the ocean during the antediluvian interval, were planes of argillaceous and siliceous loam, through which, calcareous matter, in a friable state, was largely and universally distributed by organic secretion. That term of the terraqueous constitution may therefore be compared to the *larva* state of some animals,

during which the grand metamorphosis was slowly preparing for the production of a better and more enduring earth, when that ancient ocean should transfer its mass to a new bed, possibly that of our present Pacific, Mediterranean, &c. while the secondary strata, as of Italy, France, England, and other countries, were elevated and laid dry. The physical proofs of such changes have been fully detailed in the former chapters of this work.

Calcareous matter is indispensable both as a stimulus and a food to plants, but the compact semi-crystalline texture of primitive limestone, and its insulation in detached mountain blocks, are unpropitious to its agricultural influence. When disseminated in the form of pulverised shells and marl, it becomes so beneficial to vegetation, that mixed in due proportions with alumina and silica, it may constitute a soil inexhaustibly fertile.* Hence primitive and transition districts of country, like Cornwall and Northumberland, are as readily recognised by the farmer as by the geologist.

The antediluvian dens, so skilfully deciphered by Dr. Buckland, serve unquestionably to show, that certain strata of submarine formation, richly replenished with shell limestone, had been elevated into habitable land long prior to the deluge, a corollary from our principles of the unstable equilibrium of the primeval globe. And the whole phenomena of geology concur to prove, that much of the richest

* A very productive soil, from the banks of the river Parret, in Somersetshire, afforded to Sir H. Davy four-fifths of its weight of carbonate of lime; and another yielding excellent pasture, from the valley of the Avon, near Salisbury, gave three-fifths.—*Agricultural Chem.* pp. 201, 202.

soil of the present earth, was elaborated and ripened with supreme skill, and benevolent foresight, under that ancient ocean.

By the alternate agitation and repose of the same waters, was arranged that beautiful alternation of porous and dense beds, so finely exemplified in the secondary and tertiary formations of England. To that structure is due the wide distribution of fresh waters in springs and wells,—essential to animal comfort and existence. But, for that happy alternation, every extensive tract of level land, must have been either marshy from excess of water, or sterile from want of it. Now, in consequence of the repetitions of the mineral series, and the gentle slopes of the mineral planes, one or more strata may be absent without affecting the filtering and reservoir mechanism of the system.

A third rich legacy bequeathed by the antediluvian world to its successor, merits particular notice. The ardent temperature which has been shown to have glowed at first in the primeval scene, even under latitudes much higher than our own, called forth that luxuriant vegetation round all its inland lakes, by the successive deposition of whose exuviæ on their bottoms, our coal strata were formed. Had plants passed through their several stages of vigour and decay, in these ancient times, as slowly as they do now, the coal-mines of Great Britain could hardly have existed; her fire-instinct automaton would have been unknown or inoperative; and this island, now the queen of commerce and the arts, must have slumbered ingloriously amid the fogs of her wintry seas.

What a steady career of amelioration do these three cases disclose amid apparent tumult and disaster! Nor are moral analogies wanting; for here we may perceive Divine Providence rearing with one hand a monument to all ages of the punishment of incorrigible violence and impiety; and with the other constructing a better habitation for man, the destined scene of a new covenant of grace, to be hallowed, in the fulness of time, with the footsteps of Emmanuel. The first earth had displayed, "in sight of mortal and immortal powers," how grievously the gifts of robust health and longevity might be abused by wilful free agents; the second was ordained to show how conducive a feeble frame, and a brief span of existence, might be made to the eternal welfare of responsible beings.

From the diminished area of the postdiluvian lands, and temperature of its seas, the new globe could not furnish room or food sufficient for the myriads of enormous animals which peopled its predecessor. Hence we may comprehend why the fossil elephant, mastodon, great cavern bear, palæotherium, megatherium, megalonyx, megalosaurus, and iguanodon, were not restored. Those powerful and voracious quadrupeds would have consumed the nascent herbage, which the horse, the cow, the sheep, and the other tribes of domestic animals required. Moreover, we may see that the multiplication of the former orders of wild beasts, would have been incompatible with the unbounded dispersion of man over every district of the renovated earth. The primeval compatriots of Noah were certainly restricted to one region, now sub-

mersed; for human bones moulder as slowly in the earth as those of any brute animal, yet not one of them has been found of a truly fossil character. The conclusion, indeed, may be drawn from the prodigious herds of wild beasts which prowled through these northern regions of ours, that human society was not established there. The two were, in fact, incompatible, and could not dwell together. And further, we may venture to infer from the tenor of the Mosaic history, that God, foreseeing the wickedness of Cain's progeny and their associates, benevolently restrained the progress of primeval population.

Thus we learn that Adam was 130 years old before the loss of Abel was repaired by the birth of Seth; and Seth lived 105 years, before Enos his eldest son was born. Again, Enos was 90 years old before he had Cainan, to whom Mahaleel was born in his 76th year. After 65 years Jared appeared, who had no son, however, till he was 162 years of age. Then Enoch was born, who begat Methuselah in his 65th year; but Methuselah was 187 years old before he had Lamech, whose son Noah was born in his 182d year.—The average period which each of the primeval patriarchs lived before his eldest son was born, was therefore $117\frac{1}{3}$ years.

Judging from these data, the only ones we have, the increase of population must have been very slow; Divine mercy limiting the victims of guilt and perdition. Multiplying in this temperate ratio, the race of man could not spread widely over the world, thinned as the members must also have

been, by mutual violence, the dire legacy of Cain. Whither Adam went when banished from the district of Eden, we cannot tell. We formerly suggested that he and his family might have wandered into some great southern territory, which expiated the curse of God pronounced on the earth on account of Adam's sin, by its submersion at the deluge. "And God said unto Noah, The end of all flesh is come before me, for the earth is filled with violence through them; and behold I will destroy them *with the earth*."—*Genesis* vi. 13. This language, as also St. Peter's emphatic term, απωλετο (perished), could never be spoken of a transient inundation. Would any one affirm that Egypt perishes or is destroyed every summer, when its land disappears under the waters of the Nile? But if the earthy continent which was occupied by the antediluvians, being permanently overflowed with water, perished in the deluge, a result to which physical principles have already led us, then prior to that terraqueous revolution, the climate of the primeval lands and seas, even in arctic regions, must have been warm enough, as we have seen, to breed and nourish organic productions now confined to the tropics. Hence the bony relics of the elephant and rhinoceros, found in the soils of the north, instead of being obstacles to faith, become unimpeachable witnesses to the Divine inspiration of Moses, when he relates the destruction of the *earth*, along with its guilty inhabitants.

The same causes that are now narrowing the range of fertility in many tropical countries, the same pulverisation of the surface by continued drought, the same sand-flood must have acted with

far greater force, on the relatively arid antediluvian lands. Hence most probably a great and rapidly widening zone on either side of the equator, was altogether desolate. But the proportional area of land and water established by the deluge, is adapted to a more durable and extensive fertility of the globe, from the more abundant distribution of water in every form, solid, liquid, and gaseous.

In book first, chapter third, it has been shown that round a sphere of uniform temperature, an atmosphere, composed like our own, of air and vapour, could possess no *lateral* currents, no winds, and could deposit no rain drops on the earth. All its motions would be vertical, caused by a perpetual struggle between the temperature due to the density of the air, and the constituent temperature of the vapour; whence evaporation would go on below, and simultaneous condensation above.

The warmth of the ancient ocean, and of its incumbent zones of air, would maintain a vast deal of moisture in the vaporous form; much of which on very slight diminutions of heat would precipitate on the ground in most copious dews. Thus, supposing the temperature of any region of the antediluvian globe during the day to have been 120° F. and during the night to be still 110°, as much water would be separated from it in dewy deposition, as from our atmosphere over the equatorial seas at 80°, were it chilled down to 32° below our freezing point.

The streams of ascending vapour might be considered merely as the carriers of caloric from the surface of the earth to the upper regions. But in

a sphere whose surface is very unequally heated, like the present, and whose temperature decreases rapidly from the equator to the poles, lateral currents of air and vapour would ensue, with a condensation of moisture in the form of rain-drops, more or less copious, according to the extent of evaporation in the equatorial regions, and the increasing coldness of the extra-tropical. The ancient world possessed a middle constitution between these two extremes. Its superficial temperature was not very unequable from pole to pole, and its expanse of humid surface was less relative to that of its dry land. Thus the causes of atmospheric commotion were fewer and feebler; and the phenomenon of rain must have been very rare, except on some insular circumpolar coasts. The exhalations from the tepid seas would diffuse abundance of aqueous nourishment to the cactuses, palms, and cycadeoideæ of its glowing plains.

Immediately after the flood, however, the sea-soaked lands would send up universal exhalations round the chilly globe; whence showers and rainbows would become for some time at least, almost daily appearances.

This conclusion of physical research, coincides well with our ancient history of the new-drained earth. "And God said, This is the token of the covenant which I make between me and you, and every living creature, that is with you for perpetual generations: *I do set my bow in the cloud, and it shall be for a token of a covenant between me and the earth. And it shall come to pass when I bring a cloud over the earth, that the bow shall be seen in the*

cloud. And the waters shall no more become a flood to destroy all flesh."—*Genesis* ix. The ark preserved eight intelligent witnesses, come to mature age, of antediluvian skies and seasons. Had a shower of rain been as common before the flood as it was after it, then the rainbow being a necessary result of the refraction and reflection of the sunbeams by the sheet of falling drops, must have been often seen by the family of Noah, in the land of their birth, and could not therefore be now hailed by them as an infallible seal of a peculiar covenant, graciously bestowed by their reconciled Ruler. He had just appeared in an awful light; as the inexorable judge of their guilty compatriots. Anxiously might they lift their eyes to heaven for some *new* token to inspire confidence in the stability of the *new* order of nature; to encourage them to diligence in their enjoined task of replenishing the earth.

It is therefore evident, both from the emphatic words in which the meteoric ensign of heaven's favour is announced, as well as from the holy purpose which it was ordained to serve, that it must have been equally strange, as it was glorious in their sight; for antediluvians occupying possibly on their devoted lands, a portion of its great continent, now covered by the Pacific, might never have witnessed a sun-shine shower. A canopy of clouds indeed might often be stretched in the cooler upper regions of their skies, but the aqueous vesicles in descending through the warmer aerial strata below, would return again to invisible vapour, a process fully described in Book I. chap. 3. In such clouds,

no bow could be set. Heavy dews deposited during the night and early dawn, from the well known influence of a ground chilled by calorific radiation, would supply the place of rain for vegetable sustenance; as now happens in Lima and many other regions of our present globe.

I had deduced these corollaries from the hygrometric laws laid down in treating of the atmosphere, before my attention was directed to the following curious historical notice of primeval meteorology. It affords a very beautiful, and to me quite unexpected accordance, between the results of Science and the records of Faith.

"For the Lord God had not caused it to rain upon the earth, and there was not a man to till the ground. But there went up a mist from the whole earth, and watered the whole face of the ground." *Genesis* ii. 5, 6.

This document, at which a sciolist might possibly sneer, is in reality a powerful testimony to the truth of Moses.

The rainbow thus becomes a most significant emblem of God's providential regard to man. It is a phenomenon which results from, and declares the remodelled constitution of the terraqueous sphere. It is a type of sin and suffering; of expiation and peace; a vision where the heaven-ward soul may discern the sublimest truths of Revelation and Science. "While the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease."

For a long period after the deluge, the earth, at least in its extra-tropical zones, remained relatively

damp and cold. Abbé Mann infers from an elaborate research, "that the soil and temperature of all the countries from Spain to the Indies, and from Mount Atlas to Lapland and the remotest north, have entirely changed during the course of ages, reckoning from the earliest historical documents to the present time, gradually passing from extreme humidity and cold, to a considerable degree of dryness and warmth; that is to say, from one opposite to another." *Abbe Mann's Memoirs*, I. 12.

The Hon. Daines Barrington also from a wide induction of historical facts concluded, "that the seasons have become infinitely more mild in the northern latitudes, than they were 16 or 17 centuries ago." *Phil. Trans.* 1768.

Cæsar says the vine could not be cultivated in Gaul on account of the severity of winter; though that country now affords the highest flavoured wines. The rein-deer was in his time an inhabitant of the Pyrenees; whereas, the Highlands of Scotland are at this day too warm for it. The Tiber was sometimes frozen over, and the ground about Rome covered with snow, for several weeks together. The Romans never experience such intense winter weather in our times.

This progress of heat and desiccation has produced remarkable changes on the land of Egypt. For many generations after the flood, it was a hotbed of vegetation, and swarmed with the animal tribes. Even in the time of Augustus, the granaries of Rome were filled from the corn-fields of Egypt. But the soil of the greater portion of it growing progressively more arid, has now become a mass of incoherent sand, drifted every season closer to the valley of the Nile, by the western winds, circumscribing the fields, and blasting the hopes of the husbandman. No lands capable of tillage now

remain on any portion of the banks of that river, where they are unsheltered by a mountain-ridge.

M. Denon informs us that nothing any longer appears above these sands, but the summits of ruined cities that lie overwhelmed beneath them. "How melancholy to walk over villages swallowed up by the flying dust of the desert, to trample their roofs under our feet, to strike against the very pinnacles of their minarets, and to reflect, that yonder were cultivated fields, that here grew trees, and there stood the dwellings of men, but all have vanished for ever."

Had our continents been as ancient as some have surmised, this scourge of the desert, which has committed such ravages since the days of Cleopatra, should long before that period, have effaced every vestige of human habitation from the western banks of the Nile. The relative condition of such monuments attests the progressive encroachment of the sand; for the fertility and populousness of Egypt have declined visibly with the exhaustion of the diluvian moisture. Had that great cataclysm been more ancient than the epoch assigned by Moses, Egypt ought to have reached its ultimate desolation very long ago. Not an *oasis* should now remain, no green island in the wilderness, to remind the traveller of those fruitful plains which once extended the whole way to the Nile. Thus the gradual invasion of Egypt by the sands of the desert, becomes a chronometer of our globe.

Berosus, who wrote at Babylon in the time of Alexander, speaks of the deluge nearly in the same terms with Moses, and supposes it to have happened immediately before Belus, the father of Ninus. Though the traditions of some ancient nations who trace back their origin many thousands of ages, seem at first sight to contradict

this newness of the actual world, yet when we examine these traditions more closely, we readily perceive that they are not in the least historical, and we are forced to conclude that genuine history with all its positive documents of the first establishments of nations, confirms all the above indications of natural monuments.

The Greeks confess their ignorance of the art of writing till the Phenicians taught them letters about 33 or 34 centuries ago. Long thereafter, their history is full of fables; nor do they date the first traces of their union into social hordes, further back than 300 years. The first profane historian whose works remain, Herodotus, can boast an antiquity of only 2300 years. The prior writers whom he may have consulted are only a century older. Even Homer, the master and perpetual model of the western world, preceded our age by no more than 2700 or 2800 years.

When these first historians speak of ancient events either of their own nation, or of neighbouring ones, they cite merely oral traditions, and not public writings. It was not till long afterwards that pretended extracts were given of the Egyptian, Phenician, and Babylonian annals. Berosus wrote under the reign of Seleucus Nicator, Hieronymus under that of Antiochus Soter, and Manetho under Ptolemy Philadelphus. These all belong to the third century before Jesus Christ.

Whether Sanconiatho be a veritable or suppositious author, he was not known till Philo of Byblos published his translation in the second century of our era; and though he had been known, nothing would have been found in him, as in all the writers of his class, but a puerile theogony.

A single people preserved written annals in prose before the epoch of Cyrus, namely the Jews. That portion of the Old Testament called the Pentateuch, exists under its actual form at least since the schism of Jeroboam, because the Samaritans receive it as well as the Jews, making its antiquity on this ground to be 2800 years. But since no reason

can be assigned for ascribing its composition to any one but Moses himself, this throws it back 500 years more, or 33 centuries in all. Now this work, and every other written since, however foreign to Moses and his people, represent the nations on the coasts of the Mediterranean as new. They exhibit them even as semi-barbarous a few centuries before; and moreover they all speak of a general catastrophe, an irruption of the waters, which occasioned an almost entire renewal of the human race; of which they refer the era to a date by no means remote. The Hebrew text makes the interval down to Moses only 778 years, and consequently no more than 4176 years from us.

The poetical traditions of the Greeks, the sources of our profane history for these distant times, present nothing contradictory to the annals of the Jews. On the contrary, they perfectly accord, as to the epocha of the Egyptian and Phenician colonies, which carried into Greece the first germs of civilization.

Neither Moses nor Herodotus makes mention of any great empire in Upper Asia. Even concerning Cyrus, a prince so remarkable, Herodotus, who lived only 100 years after him, avows that already three different accounts were given; and 60 years later Xenophon wrote a biography of Cyrus quite different from that of Herodotus.

It is certain that the tradition of the deluge existed in Armenia before the conversion of the inhabitants to Christianity, and the city which, according to Josephus, was called the *Place of descent*, exists still at the foot of Mount Ararat, and bears the name Nachidchevan, which has that signification.

The *Chouking*, the most ancient and authentic book of the Chinese, begins the history of their country, with an emperor called *Yao*, whom it represents as occupied in drawing off the waters, *which, having risen up to the Heavens, bathed at the same time the bases of the highest mountains, covered entirely the lower hills, and rendered the level grounds impassable.* This *Yao* dates according to some, 4166 years from the actual time, being an entire coincidence with the Hebrew chronology. Others make him about 200 years later.

"Is it possible," says M. Cuvier, "that mere accident should afford so striking a result, as to unite the traditional origin of the Assyrian, Indian, and Chinese monarchies to the same epoch of about 4000 years from the present time? Could the ideas of nations who possessed almost no mutual affinities; whose language, religion, and laws, had nothing in common; could they conspire to one point, did not truth bring them together?" Even the Americans have their Noah, or Deucalion, as well as the Indians, the Babylonians, and the Greeks.

The Chaldean observations of eclipses actually preserved and cited by Ptolemy, do not go back more than 2500 years from our times. The Babylonian or first Assyrian monarchy could not have been long powerful, since there existed all around it, many unsubjected tribes, such as the Philistines, Moabites, and all those of Syria, until the establishment of what is called the second kingdom of Assyria. The thousands of years, therefore, which the Chaldeans assumed, must have been equally fabulous as those of the Egyptians were.

The disesteem of the records of revelation was never more unluckily displayed, than by the eagerness with which some modern *savans*, adopted and struggled to defend the famous astronomical tables of the Hindoos. Though these are fabrications of a recent date, as we shall presently show, it is worthy of remark, that one of their ancient revolu-

tions of the globe is described in terms nearly coincident with the Mosaic account. Their first three *avatars*, or descents of Vishnu, clearly relate to an universal deluge, in which only eight persons were saved.

The paradoxical Treatise of the eloquent but unfortunate Bailly on the Hindoo Chronology, would have been little known in this country, and would have had little influence to depreciate the veracity of Moses, but for the elaborate commentary and eulogium of Professor Playfair read before the Royal Society of Edinburgh in 1788, and published in their Transactions for 1790. Here he announced the following conclusions; "On the grounds which have now been explained, the following general conclusions appear to be established. The observations on which the Astronomy of India is founded were made more than 3000 years before the Christian era," (consequently more than 650 years before the deluge by the Hebrew Chronology), "and in particular, the places of the sun and moon, at the beginning of the Calyougham," (the age of misfortune, 3102, A. C.) "were determined by actual observation.

"Two other of the elements of this astronomy, the equation of the sun's centre, and the obliquity of the ecliptic, when compared with those of the present time, seem to point to a period still more remote, and to fix the origin of this astronomy 1000 or 1200 years earlier, that is 4300 years before the Christian era; and the time necessary to have brought the arts of calculating and observing to such perfection, as they must have attained at the

beginning of the Calyougham, comes in support of the same conclusion.

"It is through the medium of astronomy alone that a few rays from those distant objects," (the ancient inhabitants of the globe) "can be conveyed in safety to the eye of a modern observer, so as to afford him a light, which though it be scanty, is *pure and unbroken, and free from the false colouring of vanity and superstition.*"

The Professor of Mathematics came to these conclusions after verifying the calculations and examining the reasonings of Bailly's *Astronomie Indienne*, with the most scrupulous attention. "The result was, an entire conviction of the accuracy of the one, and of the solidity of the other."—*Playfair's Works, vol. III. p. 95.*

Mr. Playfair was singularly unfortunate in this memoir, both as a Theologian and Geometer; and his complacency in the *light* that he was studying to shed, indicates a strange infatuation; for both Laplace and Delambre have demonstrated it to be *impure and broken, and full of the false colouring of vanity and superstition.* The accomplished mind and amiable manners of the Professor, gave his opinions much importance in society; whence the above conclusions so solemnly announced as mathematical truths, brought the history of Moses into contempt wherever the influence of his name extended. What a pity that some of his fellow ministers of the Scottish Church had not been able to persuade him to follow the sage counsel of Ricupero's Bishop, "not to make the world older than Moses had done!"

Laplace, on whose science the Professor pronounced so splendid a panegyric, has examined the Indian tables, in his *Système du Monde* with his customary precision.

"Every thing," says he, "leads us to conclude that they are *not* of high antiquity. They have two principal epochas which go back, one to the year 3102, and the other to 1491 years before the Christian era. These are linked together by the mean movements of the sun, moon and planets, so that one of the epochas is *necessarily fictitious.* The celebrated author (M. Bailly) to whom I refer, has tried to establish in his treatise on Indian Astronomy, that the first of these epochas is founded on observation. Notwithstanding his proofs, expounded with all the interest which he could bestow on the most complex subjects, I consider it very probable, that this epocha has been *invented* for the purpose of giving a common origin upon the zodiac, to the movements of the celestial bodies. In fact, if we assume for our point of departure the epocha of 1491, and go back by means of the Indian Tables, to the year 3102 before the Christian era, we obtain a general conjunction of the sun, moon and planets, as these tables suppose; *but this conjunction differs too much from the result of our best tables, to have taken place, demonstrating that the epocha to which it refers is* NOT GROUNDED ON OBSERVATION.

"The tables all together, and particularly the impossibility of the conjunction which they suppose at the same epocha, prove on the contrary that they have been constructed, or at least rectified in modern times." Book V. chap. I.

"The whole system of the Indian tables," says Cuvier, "so elaborately conceived, *falls to pieces of itself*, now that it has been proved that this epocha was adopted *posthumously (après coup)*, from calculations *retrospectively* made, the result of which is *false*. Mr. Bentley has discovered that the tables of Tirvalour on which the assertions of Bailly were principally founded, must have been computed towards the year 1281 of the Christian era," (only 547 years ago), "and that the *Sourya-Siddhanta* which the Brahmins esteem their most ancient scientific treatise on astronomy, pretending that it was given by revelation more than 20 millions of years since, could have been composed only 767 years before our own time." *Ossemens Fossiles, Dis. Prel. p.* 111.

Thorough conviction on this point is of such vital importance both to science and revelation, that I subjoin Delambre's decision from his admirable history of Astronomy, ancient and modern.

"The extensive treatise on Indian Astronomy, by Bailly, has been laboured with more care than any of his other works. We regret only to remark too frequently in it, that spirit of system which predominates in all his productions. Instead of giving a simple exposition of facts which may enable us afterwards to consider them in every point of view, he espouses an opinion to which he makes every thing conform. He renders it available with much address, and by approximations which are often specious. Sometimes, and especially in his Indian treatise, he intrenches himself behind an imposing mass of calculations, carefully dissembling whatever may prove prejudicial to his cause, as well as the objections

that might be advanced, and which he himself could not fail to perceive."

"If we be allowed to hazard a conjecture, we would say, that Bailly never writes but to prop a system framed beforehand; that he glances slightly over the writings of the ancients, reading them *in bad translations;* and that he runs over all the calculations in order to pick out obscure passages which may lend some countenance to his ideas."

"When we inquire why the Indians chose the remote and fictitious epoch of Cali-youg, or misfortune, we perceive, in the first place, that it was from national vanity; and in the next, that they might make all the planets start from one point, a conjunction which their method of calculation required. If we further ask, why they adopted a complicated method which employs divisions and multiplications of enormous numbers, with so many additions, subtractions, reductions, and different precepts, the answer is, that they did not wish for written tables; they wanted numbers which could be put into technical verses, even into songs, so that the calculations might be performed without opening a book. These facts, now well known through the labours of the Asiatic Society, are alone sufficient to subvert the whole system of Bailly."

"Mr. Playfair, in the 4th volume of the Edinburgh Philosophical Transactions, has spoken of the Indian table of sines, believing it to be very ancient. Consequently he is not surprised at finding no tangents in it which were not known in Europe till the 16th century. But as the idea of them is very clearly expounded in the work of Albategni, and as, in the

13th century, we find tables of tangents calculated by the Arabs, we need not wonder if they should be found in the Sourya-Siddhanta, whose date is now known to be no more ancient. The Professor is astonished at seeing versed sines among the Indians; but his memory has betrayed him, when he asserts, that the Arabs did not know them. He acknowledges that the Indians have not actually demonstrated either of the two processes which they point out for these calculations. I would be tempted to believe that they were ignorant of these demonstrations; if they had known the principle, their table would have been probably a little better. Mr. Playfair has not calculated it anew; he has not even had the discernment to perceive the error of the divisor 225, substituted, probably by an error of the copy, for the true divisor 235.5!"

Mr. Davis deduces from his elaborate examination of the Indian astronomical writings, that the Cali-youg, like the Julian period of Europe, has been compounded by a retrograde calculation. It is a principle admitted almost universally among the Indian astronomers, to assume an epoch, at which all the planets were in conjunction, in the first point of Aries. They then proceed as if this general conjunction had really been observed, and they determine the mean movements, which will give for the time of the writer, the position of the planets, such as he has been able to assign. Having thus fixed the epochs, they next travel back so far into antiquity, that the errors of the ancient epocha may vanish, when divided by the number of intervening years. Hence the mean movements employed, differ from the movements known to them, only by absolutely insensible quantities. Let there be assumed for the epoch a date 648000 years distant. Without embarrassing ourselves with the real position of the planets at that instant (a point impossible to determine), we may make all the longitudes = 0, or we may suppose a general conjunction in the beginning of Aries.

The greatest error that can possibly be committed will be a semicircle, or 180° one way or another; but $\frac{180°}{648000} = 1''$; thus by taking such a fictitious range, the greatest possible error becomes evanescent.

This idea of the Hindoo system, given by Mr. Bentley, says M. Delambre, is so natural, that I am astonished it did not occur to M. Bailly, and make the pen fall from his hand. It occurred to myself on the first perusal of M. Bailly's book, before the publication of the first volume of the Asiatic Researches, and it made such an impression on my mind, that I could never place the least reliance on the pretended proofs that he adduced, nor would I have ever seriously entered into the discussion, could I have avoided it in this history of astronomy.

Would a European astronomer in examining our Tables which go back to the epoch of 800 years before the Christian era, conclude that they were really established on observations made 2628 years ago? Such, however, is the error into which Bailly and his Scottish partisan have fallen. Astronomical calculations concur with historical documents to prove that the age of the Sourya-Siddhanta coincides with the year 1060 of the Christian era. Hence Varaha who composed that Hindoo treatise, wrote subsequently to the Arab, and long after the Greek astronomers.

"The Edinburgh Review warmly espoused the dogmas of Bailly and Playfair, and a writer in its first number affirmed that it was not proved that Varaha-Mira, was Varaha the author of the Sourya-Siddhanta.

"In the 8th volume of the Asiatic Researches," adds M. Delambre, "Mr. Bentley establishes his first assertion on proofs too long to admit of analysis here. We may affirm, however, that the objections of the critic had little foundation, and that the mean between all the results possesses every probability, that can be desired in these

matters. Moreover, Mr. Bentley confirms his proposition by a number of new calculations which we deem it needless to transcribe." *Histoire de L'Astronomie Ancienne*, I. 494.

The Hindoos transposed their history, to their fictitious system of astronomical epochs. This transfer occasioned a thousand palpable absurdities; to disguise which, they were obliged to remould their *pouranas*, to introduce fictions, and prophecies which might correspond with the end they had in view; but these very artifices more clearly display the folly of the enterprise. This system of antiquity, though fitted in many respects to flatter the national vanity, excited numerous reclamations, which continued as long as the memory of the ancient order was preserved. The necessity was then perceived of causing all its vestiges to disappear. There is, indeed, a current tradition that the Mahrattas (Maharastras) destroyed all the works of the ancient astronomers that could be found. "Finally, it appears that there does not exist at present a single Hindoo book, which can possess an antiquity higher than 1300 years, if it makes the slightest mention of these enormous periods; and that none of the romances called *pouranas* date farther back from the present time than 604 years, while some of them are more modern still!"

The opinion therefore entertained by the Hindoos about their antiquity, is founded principally on vanity, ignorance, and credulity. "Their great geographical treatises are merely a tissue of the most incredible absurdities, of which we shall say nothing else here, out of regard to the honour of the Hindoos. One of them is of the 5th, and the other of the 10th century of our era." *Ibid.* p. 500.

In concluding my survey of the primeval world, while I readily acknowledge that many of my views are but partially developed, or faintly shadowed forth, and that some of them may want confirmation, yet I trust that the accordances brought out between scientific induction, and sacred history, are neither fanciful, nor overstrained. Well aware of the morbid

resilience of the human mind against arguments of this nature too closely pressed on its acceptance, I have omitted to notice in the progress of my inquiries, several analogies on which it would have been not undelightful to expatiate. Such as belong to the deluge the reader will spontaneously recognise, on comparing the graphic description of Moses, with my delineation, directly drawn from physical principles. For a popular narrative what language could be happier than the following: "The same day were all the fountains of the great deep broken up, and the windows of heaven were opened!" The atmospheric calm, also, which prevailed during the consummation of the catastrophe, the resulting tranquillity of the circumfluent waters, and the majestic buoyancy of the Ark, are well indicated in the record. "The waters increased, and bare up the ark, and it was lift up above the earth. And the waters prevailed, and were increased greatly *upon the earth;* and the ark *went* upon the face of the waters."—*Genesis, chap.* vii. And long before the diluvial deflux acquired its destructive velocity, we are informed that the proto-ship was quietly grounded on the summit of a mountain.

I now dismiss these lucubrations, humbly hoping that they may promote the study of a new, but magnificent field of knowledge, and a far greater good than all physical science can bestow, one which the finest philosophical spirit of the age, justly declares he would prefer to every other blessing, as most delightful and most useful to him—a firm religious belief.*

* Sir H. Davy, in Salmonia, p.136.

EXPLANATION OF THE PLATES.

Plates I. II. III. IV. and V., representing the fossil shells of the successive mineral strata, require no explanation, as the generic and specific names, according to Mr. Sowerby's nomenclature, are annexed to each shell. The mineral conchology of this eminent naturalist is a work of great merit, which every practical geologist should have in his hands, as it will enable him to discriminate with accuracy the several secondary and tertiary formations from one another. The ammonites occur in all the formations, up to the chalk inclusively, in which they abound. The figure on the margin is a section of an ammonite, to show the course of the siphuncle, or channel of communication between each successive cell in the spiral. It is believed that the membranes of the molluscous animal in the living state enveloped this shell, as the sepia and nautilus do theirs. See p. 236 at top.

Plate VI. is a lithographic representation of the petrified stem and leaves of a plant akin to the *cactus cylindricus* of Martius. See p. 449.

The fossil was found in the neighbourhood of Swinridgemuir in Ayrshire, in a stratum of very hard coal-sandstone. The whole freestone bed is thickly interspersed with these stems, having the leaves No. 4 attached to them. In the blocks cut out by the quarriers, the leaves are seen radiating, as it were, from the stems in all directions, to a length of from 18 to fully 24 inches. The stems are frequently enclosed in a thin case of stone, resembling the bark of a tree, with a surface like that of the interior organic form, through which case, the leaves pass, being there attenuated.

The workmen have lately begun to quarry a lower stratum, which is much softer, and seemingly destitute of vegetable remains. A coal mine exists in the immediate neighbourhood.

Fig. 1, Represents the fossil stem upon a considerably reduced scale.

Fig. 2, Is a portion of the natural size, to show the surface figures more distinctly.

Fig. 3, Is a magnified view of one of the cicatrices or scars; whence the leaves have fallen, with the central umbilicated papilla.

Fig. 4, Portion of the stone that enveloped the stem, in which the leaves are imbedded; of the natural size.

a, Corresponds to the pith of the stem, nearly in the axis of the fossil, from which a soft or spongy matter may be extracted by the fingers from some specimens; longitudinally wrinkled on its surface.

In the coal-measures immediately round Glasgow, petrified cactuses are very common. I have one from Mr. Dixon's coal-field, in the form of a compressed stem, (somewhat like an opuntia,) covered with a thin crust of pyrites, veins of which pass also through it. The fossil is attenuated at the edges. The surface is areolated with ovate umbilici disposed in diagonal lines parallel to each other. The umbilici with their central tubercles, are in several cases filled with carbonaceous matter, as might be expected from the circumstance of the petrified plant having been enveloped in a mass of cubical coal.

Plate VII. Represents the cavern of Gaylenreuth, as delineated by Dr. Buckland.

A. The entrance; a passage from 6 to 10 feet high, opening outwardly in a steep cliff, and expanding inwardly into the large chamber B, studded with stalactite on its roof, and stalagmite on its floor, which uniting in the centre of the chamber, form a species of pillar.

C. Crust of stalagmite, forming a nearly complete carpet

to the chamber B, but broken into patches in the lower apartment F.

D. Bed of diluvial loam, mixed with bones and teeth.

E. Hole dug in the mass D, in exhuming the bones.

F. Second chamber, separated from the first, by a mural precipice.

G. Enormous congeries of bones, lying among loose earth in a deep cavern, which descends from the side of the chamber F. H, the empty vault of the cavern over the bones at G.

I. Mass of bones 25 feet deep, mixed with pebbles and loam. It is cemented by stalagmite into a solid osseous conglomerate, somewhat like the Mediterranean breccia.

K. Well, sunk 25 feet into L, in order to extract the bones.

KK. Cavities dug at the bottom of the well K; but not perforating through the breccia to the subjacent limestone.

L. Another artificial cavity dug in the side of I, in search of bones.

M. Low corridor connecting the chambers F and N.

N. Small innermost chamber, on whose floor the well K is sunk. Dr. Buckland considers this to have been originally the roof of a deep cave, which has been filled by the mass of bones and diluvium I I.

LIST OF WOOD ENGRAVINGS.

THE END.

ERRATA.

Introduction, page xxxix, line 21, *read*

"Grave ne rediret
Seculum Pyrrhæ, nova monstra quest*um*"

Ibidem, page l, line 29, *read* "productæ."

Page 24, line 3, *read* "its own account."

— 93,	— 11,	*for* "their"		*read* "its."
— 125,	— 6,	— "phenomenon"		— "phenomena."
— 251,	— 5,	— "medus"		— "medusæ."
— 485,	— 16,	— "latter"		— "former."
— —	— 19,	— "former"		— "latter."

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SHELLS OF THE MOUNTAIN LIMESTONE.

SHELLS OF THE LIAS

ngd for Ure's Geology

by Joseph Swan

SHELLS OF UNDER OOLITE.

for Ure's Geology

by Joseph Swan.

SHELLS OF CORNBRASH AND UPPER OOLITES

Eng.d for Ure's Geology *by Joseph Swan.*

SHELLS OF THE CHALK & SUPERIOR STRATA

Engd. for Ure's Geology

by Joseph Swan

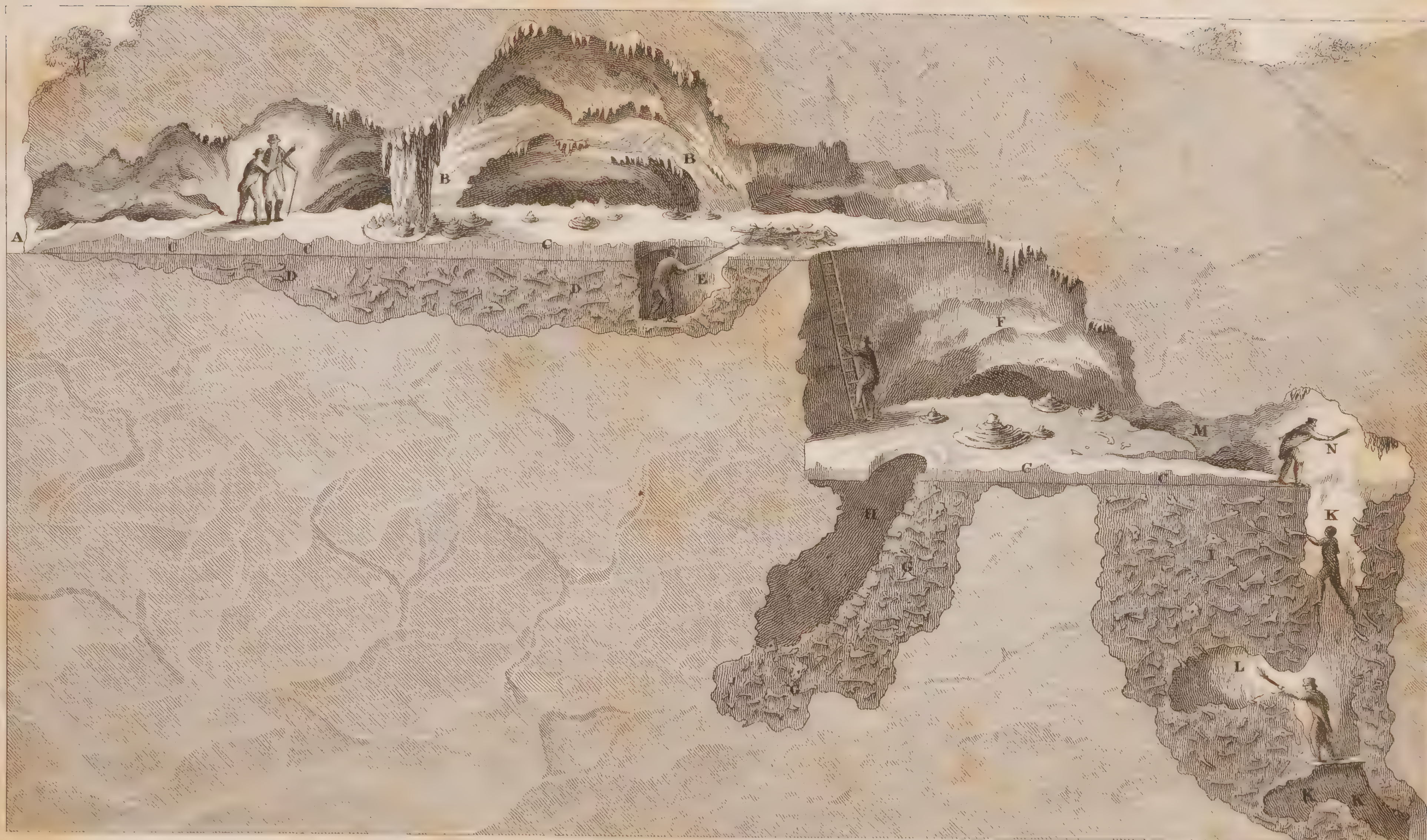
Fossil Plant in Coal Sand stone.

Akin to the Cactus Cylindricus of Martius.

Ure's Geology.

Drawn by D. Macnee. *Printed by C. Hullmandel.*

PLATE VII.



VERTICAL SECTION OF THE CAVERN AT GAILENREUTH IN FRANCONIA

Eng.d for Ure's Geology by Gray & Son.

N_4O –

N_2O –

NO_4

NO_5